USE OF THE VAR METHOD FOR MEASURING MARKET RISKS AND CALCULATING CAPITAL ADEQUACY

Peter Badík

Continued from No 2/2005

Choice of confidence interval

The suitability of a confidence interval varies according to our purpose. If our aim is to test the VAR method and its results, it is better to work with a smaller interval. The problem of a high interval is that the losses greater than the calculated VAR value are very rare. If, for example, we use a 99% confidence interval for a one-day period, then losses exceeding the VAR occur only 2.5 times a year. If we want to test the model with a certain accuracy, then the higher confidence interval we use, the more observations we will need.

The choice of confidence interval also depends on the overall aversion to risk. In the case of conservative portfolio management, managers will require a greater volume of capital for covering potential losses. If the size of this capital is expressed with the help of VAR, then in the case of more conservative management it will be better to select a higher confidence interval.

The last factor that needs to be taken into account is the possibility of comparing VAR values between portfolios or institutions. It is clear that a simple numeric comparison of VARs calculated on the basis of different confidence intervals and time horizons is nonsensical. The VAR value must in this case be recalculated to the same base. If we assume normality in the distribution of revenues, then this recalculation is not a problem. We can easily derive the relationship between a VAR based on 99% probability and that on 95% probability, since we know that the 99% probability interval represents 2.33 times the standard deviation, and the 95% interval represents 1.65 times the standard deviation. Therefore:

$VAR_{99\,\%} = 2{,}33/1{,}65 \,.\, VAR_{95\,\%}$

A similar situation, under the condition of normality, concerns also the comparison of a VAR based on various time intervals. Here it applies that:

$$VAR_{t2} = \sqrt{t2/t1} \,.\, VAR_{t1}$$

For the purposes of capital adequacy the NBS measure sets a 99% confidence interval and a 10-day time horizon.

Selecting a model for calculating VAR

In the following part I shall summarise the three basic methods used in calculating the VAR. Despite this being a seemingly purely theoretical problem not concerning risk management, I am convinced that in fact the opposite is true. Creating a proprietary information system of sufficient quality for calculating VAR is financially very costly, which requires significant know-how, many banks instead purchase specialised software for this task. Often this software is a component of a complex front-office solution[1]. Even in the case where risk management does not directly deal with the development of the system used, it cannot be taken as a black-box solution, without a knowledge of its functioning and the method used.

A detailed analysis of the models used for calculating VAR is, of course, beyond the framework of this article. I shall nevertheless attempt to outline their basic characteristics and highlight those features that should guide a bank in its decision of which model to use.

At present there are in theory three models developed for calculating VAR: the variance-covariance, historical simulation and Monte Carlo models. For capital adequacy purposes any of these may be used. The choice however should certainly not be left to chance. In its selection the bank should answer at least the three following questions.

How much finance and human potential are we willing to spend on measuring risk? Each of the models mentioned places different financial and personnel demands on risk management. A bank, while it will probably purchase software for calculating VAR from a specialised firm, and therefore it may seem that the staff responsible should take care only of the correct input data, in fact the opposite is true. The regulatory authority will strictly require bank staff to demonstrate a knowledge of the model used. It is clearly also

[1] Such a solution can sometimes seem very advantageous, due to the single integrated database naturally contained in the front-office system, where the problem of exporting data to another system is absent.

in the interest of the bank's management that their risk team understands the basic principles of calculating the VAR, knows which factors have an important influence on the calculated value so as to be able to explain sudden changes in the VAR, etc. In the case of a complicated model, such as the Monte Carlo, a thorough knowledge requires a highly professional approach, where the administration and maintenance itself of the system are very demanding. For a smaller bank that cannot afford such large costs for risk management, it will therefore be better to select a simpler and less expensive model.

How liquid is the market in which we are operating? The liquidity of the market influences the volatility of the market data used as the risk factors in calculating the VAR. In illiquid markets sudden changes in interest rates, prices, or exchange rates are relatively frequent. Extreme values appear often. It may many times be impossible to ascertain actual market data. We can take the Slovak stock market as an example. It essentially does not generate market prices upon which a serious analysis can be performed. Each of the three models reacts to this inconsistency differently. A question is whether we can assume normality in the distribution of risk factors, or whether this assumption is an oversimplification.

What is the composition of our portfolio? In the case of a portfolio in which non-linear positions, such as options or bonds feature significantly, it will be more appropriate to use a model that does not assume a simplification with regard to the normality of risk factors, or the linear dependency of revenues on risk factors.

Model based on the variance-covariance matrix of risk factors (the variance-covariance model)

The oldest model, which is founded on the application of the Markowitz Portfolio Theory and based directly on equation (4) in the previous part, issue no. 2/2005. The basis is a massive simplification, where all risk factors (we can say that all risks) are governed by a normal distribution and where the VAR is a multiple of the standard deviation of the portfolio's revenue, in the manner depicted in equation (4). The standard deviation of the portfolio is a linear function of the individual volatilities and covariances of its components, as predicted by the Markowitz Theory.

The estimate of the VAR is then simply a matter of using the variation-covariance matrix and information on the relative size of the individual components of the portfolio, and subsequently multiplying the resulting standard deviation and the parameter of the selected confidence interval by the overall portfolio value. This is, however, not at all that simple, for at least three reasons. The first is that very often the revenue (profit / loss) is simply not a linear function of the risk factor (for example an interest rate or exchange rate), as it is in the case of bonds or options. The first approximation can be the first derivation of the price according to a risk factor (in the case of options this is according to the price of the underlying assets, and in the case of bonds this is according to the interest rate) and the use of the delta equivalent, or duration. In the case of some portfolio types containing a large number of non-linear positions, even this however need not be sufficient and we will still have to make further adjustments to allow us to keep with the variation-covariance method.

A further problem we must solve is that we will probably not have the volatilities and correlations for all components of our portfolio. In order to calculate the standard deviation we need to know the variances and correlations between each component of the portfolio. However, a portfolio can be very structured with an "n" number of various components, meaning that we will work with a matrix having the size "n x n" and a huge quantity of data, enabling us to calculate its individual components. If we were to ignore the demands of such a calculation, for which we would for large portfolios undoubtedly need high-quality hardware, the problem would remain that certain essential data simply do not exist. How do we find the covariance of a recently-issued share or bond with the rest of our portfolio? Moreover, from the statistical aspect there are certain limitations, which require a minimum number of observations on the basis of which the variation-covariance matrix can be calculated. The way to resolve this situation has two steps. The first is to express each component of the portfolio as far as possible by means of a limited number of positions of the same type. This is done through a breakdown to the building blocks of individual instruments. A bond in a domestic currency is divided into a series of interest rate positions pertaining to the coupons and repayment of principle, currency swaps are divided into interest rate swaps in the individual currencies and into foreign exchange positions, shares are expressed by means of a market index – the beta coefficient, etc. In the case of interest rate positions we are still left with many positions of differing maturities. The second step in the case of interest rate positions is therefore accumulation to a smaller number of maturities. This process is termed mapping. We select significant points, e.g. 1M, 3M, 1Y, etc., which are usually covered by points quoted on a yield curve and we recalculate the values of positions whose maturity is not equal to any of the points. In this way we attain a synthetic position representing an approximation of our actual. All this is however easier said than done. To create a synthetic portfolio correctly, so as to not lose the properties of the original portfolio is a far from simple matter and the most accurate processes are usually demanding both mathematically and computationally.

Advantages

The advantages of this method that could lead a bank to favour it over others are primarily the low hardware costs, resulting from its low demands as regards computing power. The covariance matrix will in a typical Slovak bank be limited to several dozen risk factors. It must however cover all risk positions in the portfolio, i.e. all currency exchange rates used, a relatively detailed yield curve of the main currencies and less detailed curves of other more exotic currencies. Thanks to the low demands in calculation, it is possible to operate it according to need even several times per day, something which is important if we want to actively work with VAR, to ascertain the influence of changes in the portfolio composition and size on the VAR, etc. Through this method we can administer even a very large portfolio, mainly if it contains simple linear positions and if the risk factors are indeed governed by a normal distribution.

An advantage also lies in by-products which arise in calculating the VAR. The mapped interest rate positions represent, for example the GAP, which can then be a secondary output from the system managing the VAR calculation. The same can be said of the calculation of the Basis Point Value and the standard deviations of risk factors.

Disadvantages

The greatest disadvantage of this method is the assumption of normality in the risk factors' distributions. This simplification brings with it many advantages, but can sometimes be far from the truth. Non-linear positions are another problem. If they feature significantly in a portfolio, the portfolio's value will not react to changes in risk factors as predicted by the model (i.e. in a linear fashion) and the source of the risk will escape us. If a bank wants to calculate the VAR from a portfolio where option feature to a large degree, and if furthermore these have a relatively large time horizon as regards the internal value, then consideration should be given to using a different method.

The quality of the input market data is of key importance. It is worth considering whether in the case of exotic currencies it is worth using all points of the yield curve. If in the case of a less liquid market a quality benchmark bond is lacking for a certain period, or the swaps market is illiquid, banks will then quote this point with greater volatility, which will lead to a higher VAR value. For example, in Slovakia until recently there was no common platform on which banks would quote a bond benchmark. This role has now been fulfilled for about a year by the SKBMK website.

Historical simulation

The idea underlying historical simulation (HS) is relatively simple. It requires that we first identify all (risk) factors influencing the value of our portfolio, i.e. interest rates, exchange rates, share and commodity prices. We obtain historical time series of these variables. We determine the value of the portfolio on the basis of current risk factors and subsequently retrospectively ascertain the value of the portfolio in the current composition and risk factors of past periods. In other words, we find the market value of the portfolio under current and past market conditions. Changes in the portfolio's market value between individual historical periods create a distribution of revenues which we can expect is a good estimate of the future distribution of profits / losses. From the distribution obtained in this way we can determine the relevant percentile according to the required confidence interval, which will represent the VAR value.

Advantages

The concept of HS is very simple, which helps not only risk managers, but also facilitates the reporting and understanding of the VAR for senior management. A bank will already have most of the necessary data and use it, for example, for daily market-to-market revaluation, or if, conversely, a bank does not perform m-t-m (or does so only for a part of its book), this feature can be a welcome by-product in the implementation of HS. In the case of a small number of risk factors and a small portfolio, HS can be calculated even without complex software, e.g. in Excel.

The greatest advantage of HS, however, is that we do not have to make any assumption as to the historical distribution of revenues and determine a specific distribution function for this distribution. Furthermore, a by-product of HS can be numerous statistics providing a more accurate picture on the distribution of revenues, such as the taper or skew of the revenue distribution. It is not necessary to determine the correlation coefficients of risk factors and to perform difficult operations with matrices. HS can be applied to any type of position under the condition that we have available all the risk factors determining its value.

Disadvantages

A serious shortcoming of HS is its total dependence on specific historical data. The basic presumption is that the past, as captured in the market data, contains an accurate prediction of future risks, from which it ensues that the risks we will face in the future should be the same as those faced in the past. While this problem relates also to other methods of calculating the VAR, in the case of HS its influence is much more apparent.

A problem arises, if the data for the monitored period are "unusual". If they are too volatile, the VAR will be overvalued, and conversely should we capture too calm a period the VAR will be undervalued.

If our data captures an event that will happen only very improbably in the future, this will influence the VAR until we stop capturing the event in the historical series of risk factors. At the moment when a given fluctuation drops out of the historical series, the VAR will change significantly.

The HS also has difficulty coping with systemic changes influencing risk factors. If, for example, there is a change in the exchange rate system and a one-off devaluation, or a systemic change in interest rates, we will continue to use the old risk factors for assessing positions, despite the fact that there is no reason to assume that a similar change will occur again. Systemic changes could have a negative influence in the case of an HS applied in a Slovak bank, since systemic changes have included, for example, the reduction in interest rates in October 2002, the recent reduction in interest rates for HUF, or the forecast change in the yield curve upon Slovakia's entry to ERM II. In connection to this an increasingly important question, mainly in emerging markets, is that of how long a historical time series should be chosen. On the one hand we must ensure a sufficient number of observations in order for the estimate to be accurate. Nevertheless, in the case of too long a series market conditions can change so much that the very old observations of risk factors will only have a small coherence with their future values.

Many of these problems can be prevented, or their impact mitigated, by weighting individual revenues according to the age of the risk factors used. The more recent observations shall be assigned a greater weighting, the older a lower weighting. In this case the VAR will be significantly influenced by the choice of weightings we assign to time periods and we will have to make a number of assumptions on the models by which we assign the weights.

Monte Carlo Simulation Method

The Monte Carlo method (MCS) is the most demanding of the methods mentioned, it is however theoretically best qualified to provide sufficiently accurate estimates of the VAR. We can simply summarise the principles of the MCS methods as follows. First of all, we select and structure a model describing the behaviour of a risk factor, for example of a selected interest rate, or exchange rate, etc. We define the input (independent) variables and then estimate the model's parameters. In the next step we feed in random numbers, or more precisely said, pseudo-random numbers, limited by certain conditions, into the model created. The value of the set of risk factors gained in this manner will then determine the value of the portfolio. In the case of a sufficiently large number of repetitions a distribution of portfolio revenues will be a good estimate of the actual distribution.

Advantages

The MCS is a very strong instrument for estimating the VAR and can be used for almost any type of portfolio, however complex or exotic. It can work with the price risk connected with non-linear positions, which present significant problems for other methods, based on assumptions of a normal distribution. It can also work with prices instruments, if they depend on more than one stochastic variable, or with correlations and volatilities changing in real time. It is most appropriate for work with portfolios of standard options, or also much more complex option structures including those where the price cannot be calculated by a standard analytical procedure (some American options). The MCS is often used by large banks for pricing these sorts of complex derivative instruments in an effort to avoid the limitation resulting from classical analytical methods, which mainly in the case of exotic derivatives can cause significant difficulties to any correct price estimate. Where a bank uses models for revaluing its portfolio, it is natural that it will try to use its technical and professional capacities also for risk management by means of MCS. Conversely, if a bank decides to use the MCS for calculating the VAR, its by-product can be a better pricing of instruments in its portfolio.

Disadvantages

Compared to other methods the MCS entails much higher personnel and technical costs. For each risk factor a model must be prepared, involving estimating its parameters, and after some time possibly also reviewing and monitoring its appropriateness. For an average Slovak bank, which would use MCS only for monitoring exchange rate and interest rate risk in general this means several dozen models. In the case of an institution with positions in a large number of currencies, with stock or commodity positions, this figure would yet again be significantly increased. In order for the MCS model to be reliable, it is necessary at each calculation of the VAR to perform a sufficiently large number of repetitions, i.e. recalculations through all the models used. In the case of a large number of risk factors, this is also a very demanding task in terms of computing power. Slovak banks should opt for this method only in the case that they are willing to make a significant investment in risk management and have a quality staff for administering the system.

Due to the demands and complexity of this system it is sometimes difficult for a bank's management to keep track of what their risk managers actually do. MCS would bring the greatest benefit to banks with large derivative positions.

A bank's choice of which model to use for calculating the VAR is then a very important step, and should be taken with regard to:

- the specifics of the positions for which the model is to be used. A bank here should take account of its largest positions and adapt the choice of model to them,
- risk management personnel capacities,
- technical possibilities and costs for risk management,
- prospects and expected development in the bank's business.

Backtesting

Following the selection of parameters, methods and following successful implementation, it is necessary to test whether our estimate of the VAR approximates to actuality, and thus whether an adverse result is in fact not occurring more frequently than we would have predicted under the selected parameters, or conversely whether the number of times the VAR value is actually exceeded is not too low (in this case we would have over-valued the VAR)

Backtesting is based on the principle of calculating the current market value of the portfolio. On day "T" the portfolio is re-valued at current market prices and its market value (in essence the m-t-m value) is found. On day "T+n" the same, unchanged positions are again valued at current market prices, where "n" is the number of days for which it was decided to calculate the VAR. The difference between these two values expresses the growth, or fall, in the portfolio's value, under the condition that its content remains unchanged. This difference is then compared with the VAR estimate on day "T".

In the case that backtesting shows that the model for estimating VAR is imprecise, it must be corrected (a change to a probability interval, time period, change to the calculation of the correlation matrix, a change to the weightings we assign to historical data, or a change to the model's construction, or possibly even a change of method).

Stresstesting

All the preceding methods of expressing risk based on the VAR concept have one weakness in common. All of them are derived from past observation and assume that on the basis of observing the past we can create a good estimate of future occurrences. In most cases this assumption is sufficient. Future occurrences are a continuation of processes underway today and yesterday, the conditions on which these processes are founded change relatively slowly, etc. However in the case of unprecedented unexpected events such as political crises, terrorist attacks, or events that occur so rarely that it is not possible to include them in models, e.g. various currency deflations, administrative interventions, etc.

Despite the fact that such situations are extremely improbable, risk management must reckon on them and have an idea of their impact. Moreover, it is necessary to be aware that in the case of an e.g. 99% probability interval and in a 1-day time interval an extreme event, which we will not capture by means of the VAR, can occur perhaps 2_ times a year. For all these cases stresstesting results should always be available to management. Risk management should determine several risk scenarios and calculate what impact the scenario would have on the value of the bank's portfolio.

In my opinion there should be three types of stress scenario:

- Relatively probable scenarios – representing a change in risk factors by 3 to 5 standard deviations. We can include here also some standard stress tests, such as parallel shifts in yield curves by 100 or 200 points, various turns of curves, etc.
- Tests based on predictions of future development based on qualified estimates, e.g. predicted linking of the koruna to the eurozone, or ERM II, interest rate changes by monetary authorities, etc.
- The last type are catastrophic, worst-case scenarios ensuing from dramatic events, e.g. terrorist attacks, wars, etc.

Assessing such scenarios is an essential supplement to the various VAR methods. They together then form a comprehensive picture of the market risks to which the bank is exposed and enable the bank to be prepared and able to react to each alternative in the future environment.