FINANCIAL RISK INDICATORS TO EVALUATE INVENTORY MANAGEMENT POLICIES

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Abstract

This work takes the theory behind the VaR (Value at Risk) indicator, as it is used at financial sector, and applies it to economic valuation of projects in the real sector, particularly in manufacturing, and specifically in the valuation of economics effects of holding some inventory policy. The idea is to study the VaR over the Present Value of a Company, and the variations induced on this indicator for the changes made to the account "working capital", related to inventory policies. The VaR will be calculated using Monte Carlo Simulation, and a case study will be presented and analyzed.

***Keywords**:* Value at Risk, Inventory Management, Project's Economic Valuation, Monte Carlo Simulation

Resumen

El presente trabajo utiliza el indicador financiero conocido como Valor en riesgo (VaR) de uso común en el sistema financiero, para el proceso de análisis económico de proyectos en el sector real, particularmente en manufactura y específicamente en la evaluación de los efectos económicos derivados del mantenimiento de diferentes políticas de inventario. Se revisa el valor en riesgo del valor de la compañía, a partir de las variaciones inducidas por diferentes políticas de inventario sobre el capital de trabajo de la empresa. El cálculo del VaR se obtiene mediante la técnica de simulación de Monte Carlo. En el artículo se presenta también un caso de aplicación de los conceptos estudiados.

Palabras clave: Valor en Riesgo, Gestión de Inventarios, Evaluación Económica de Proyectos, Simulación de Monte Carlo

1. Introduction

The usual approach for the economic valuation of real sector projects starts with the creation of a cash flow, in which the analyst make some estimation of future incomes and expenses, in such a way that is possible to account for net cash flows. For most real projects, many of its parameters are random variables, which turns the valuation into a complex problem. Simulation is usually used for handling this situation, but the analysis of simulation outputs requires statistical tools, and statistical indicators, specially for comparisons purposes between different alternatives and scenarios.

The Value at Risk (VaR) indicator and other performance measurement that share its logic are today widely used in financial institutions, as well as in the economic valuation of portfolios and business within the financial sector. VaR is a single number that measures the maximum potential looses in present value of a portfolio, as long as the market conditions behave in a usual way, which means, the market exhibits conditions related to its historical data. The idea of having a 'portfolio' belongs pretty much to the financial sector, but in a general way, one can see a real project as a portfolio, in the sense that you need to make an investment for having the real project in operation, and after the investment has been made, one can expect some economic returns in the future. Just like buying some treasure bills right now, and selling them after a while at a different price, hopefully higher.

The effort required for valuing a real project is usually higher than the required for valuing a financial portfolio, especially if one consider a portfolio composed with financial standardized instruments. For a real project, in each case the analyst should understand, specify and model the intrinsic nature of the business, trying to identify those elements that affects in a major way the economic value of the project. Even if one is considering a couple of business in the same market and selling basically the same final products, modeling every one of them is a different exercise, related to the nature of internal process and decisions of every one of them.

2. Problem presentation

Real projects, as well as financial instruments and portfolios, are affected for uncertainties and risk observed in several market factors. Traditional methodologies for valuing a project uses a static representation of critic future parameters values, specially those parameters that are beyond the control of project owner, but that affects in a serious way main performance indicators. A single static forecast of critical parameters does not look like a good idea to valuing real projects, since they are finally going to face a lot of risk, and so, final values for parameters can be too much different from the ones forecasted in a single scenario.

One approach to deal with risk has been the use of scenario formulation instead of the use of a single forecast. Scenario generation has at least two problems in its implementation: the first one is the identification of a set of scenarios that really represents the future possibilities of the real world system; the second one is the assignment of a probability to each scenario, since every one of them are no necessary to occur with the same probability. Since the possibilities of behave for a real system are pretty much uncountable, the process of determining a subset of scenarios that fully represents future behavior is not an easy task. Also, assignment of probability chance for every scenario is sometimes a subjective process, and so, is exposed to human misperceptions.

Assuming that one can set up a formal representation of a real system (mathematical and computational), through which is possible to calculate performance indicators given a set of parameters constructed from the real world, a better approach to the analysis of real system is the use of simulation. The basic idea is to generate as many scenarios as possible, and for every realization of the parameters, to calculate the performance indicators. At the end, the analysis is focused on the several values observed for those indicators. Analysis is usually done by identifying probability distributions functions associated to the performance indicators.

Analysis of real projects under risk conditions is a topic that has been in the arena of academics and practitioners for a long while. The present work uses the idea of some previous documents, in the development of a performance indicator that deals with risk quantification, while at the same time measures how good is the project from a financial point of view. Particularly, the problem is to quantify the risk exposition of a manufacturing system that is a result of setting up an specific inventory holding policy. The expected result is an indicator of a VaR type that will be useful for selecting an inventory policy that maximizes the present value of a project, while exposes the company to an adequate risk level.

3. Preliminary research

Hill et al (2005) proposed a discounted cash flow approach for finding a good inventory policy, in a system that uses periodic revision (every R units of time) and the amount ordered each time is variable, calculated as the difference between a maximum inventory level previously determined (denoted as S), and the inventory available by the time the revision is made (This inventory policy is often referred as R,S). Authors claims for concentrating the attention in the cash flow derived from holding the inventory policy, instead of calculating just the cost related to it. Demand is modeled by using a Poisson distribution. They considered a deterministic lead time and unsatisfied demand is backordered. The optimal inventory policy is derived using NPV (Net Present Value) as a performance indicator.

Disney and Grubbström (2004) studied a manufacturing system also with an R,S inventory policy, in which the demand is modeled using an stochastic autoregressive process. The production/distribution lead time is setting up to one period, and the demand is forecasted using exponential smoothing. They approach the problem of determining a inventory holding policy using cost performance, but, including new cost elements, in particular, the cost of requiring additional production capacity, as well as the cost of having extra production capacity. Those two cost elements are not considered as necessary symmetric. Every cost element is modeled using the usual lineal form of the functions. The main conclusion they have reached is that optimal policies coming from the usual cost approach are not necessary optimal in the presence of new cost elements, as the ones mentioned before. Also, they have found that if one considers the cost of Bullwhip effect as a part of the cost of holding some inventory policy, then the optimal values derived from usual approach are also invalid.

Bulinskaya (2003) introduces the analysis of inventory management in the framework of corporate risk management. His work start by making some critics to usual cost approach, specifically that the cost is calculated in a static framework, while the real systems are dynamic by nature, and also that usual approach does not include capacity constraints, and so, it is supposed that in the future, any amount of product that came out from applying an inventory policy would be possible to acquire, while in the practice there are budget constraints. The point of view used by Bulinskaya is that the inventory is just another investment option to the decision maker, and so, determining the optimum inventory policy can be done by solving and investment selection problem, in which one can include other possibilities (assets) besides the inventory. The author uses the approximation of Cox-Ross-Rubinstein for modeling the financial market, and proposes some optimal strategies derived from that formulation.

Naim et al (2007) studied the problem of selecting an order policy in a planning and control production system. The studied is carried over using a simulation model widely used, referred as IOBPCS (Inventory and Order-Based Production Control System). The performance indicator that is optimized is again the NPV, but some extra cost elements are included. The concept of variance cost is introduced, defined as the cost in which a systems incurs when it is not in perfect control with respect to some goals previously defined. Two variance cost are considered: the cost of not being able to reach a production goal, and the cost of holding more or less inventory than the amount expected. Authors used a formal representation of IOBPCS model using differential equations, that is solved using the approach of Laplace Transformation. The performance indicator including variance cost is used in the valuation of make to order and make to stock systems, concluding that the specific cost structure of every manufacturing system is a critical factor in the selection of an optimal inventory holding policy.

Tapiero (2005) introduces the use of VaR (Value at Risk) in the optimal selection of inventory policies. The main idea of Tapiero is to introduce an ex-post analysis, instead of the usual ex-ante approach. The ex-post analysis is possible by measuring the deviations observed from a performance indicator related to the expected values of it. With respect to the inventory, Tapiero argues that a manager would value in a different way the process of having more inventory than the expected, that the process of loosing demand for not to have enough inventory. Tapiero introduces the concept of a right decision cost, which is supposed to be the cost of taking a decision from which no future deviations occurs. The VaR is then suggested for this ex-post valuation, but some difficulties appears due to complexity of mathematical expressions, some of them not having analytical solutions. The VaR is identified as a good indicator, also because the parameters required for its calculations, probability an a confidence level, can be related with technical characteristics of inventory systems.

Luciano et al (2003) explores the possibility of using VaR in the context of inventory management. They used both criteria, cost minimization and profit maximization. Ordering and holding cost are included in valuation of inventory policies. Since probabilistic parameters are allowed, the authors study the probability distributions that results for performance indicators. Upper and lower bound limits are calculated for VaR as a way to estimate its confidence level. Numerical procedures are recommended, due to complexity related to modeling real manufacturing systems. Main conclusion is that big mistakes can be obtained if normality is supposed a priori for optimization criteria. Numerical exploration of solutions, including simulation, is highly advised.

Some other research have been done about the evaluation of real projects, specifically projects within the manufacturing sector, that uses financial indicators as performance measurement or optimization objectives, the readers are advised to check out these ones: Giri and Dohi (2004), Van der Laan (2003), Van der Laan y Teunter (2001), Luciano y Peccati (1999), Grubbström (1999), Followill y Dave (1998), among others.

4. Case presentation

A Colombian company that produces copper wire got a contract with a Canadian raw cupper supplier, that states that Canadian company will send 100 TN (tons) of raw cupper each month (99% pure). Due to market conditions, the price that will be paid for the raw material is expected to fall between U$1.360 and U$1.400. All raw material consumed in a particular month will be transformed in final product, which in turn will be sell the same month (there is not inventory of final product). The expected price for each TN of final product will be U$1.800. Several cost elements are considered related to inventory management (to facilitate the understanding of the cash flow construction, all the cost elements are related to inventory levels): holding cost (4% of average inventory per period); management cost (5% of average inventory per period); and insurance cost (5% of final period inventory). Transform cost (personal labor + indirect cost) are estimated as 10% of the value per each TN. The capital cost for the Colombian company is assumed to be 1% a month, in U$ dollars. Finally, consumption of raw material is expected to follow an uniform distribution, with lower bound equal to 90 TN and upper bound equal to 100 TN.

It should be noticed that due to contractual limitations, the Colombian company can not set up any particular inventory holding policy. The inventory that is going to be in the factory will be the result of a combination of a stochastic process, related to stochastic conditions of final demand, and the fact that every month 100 TN of raw material will be available for production, due to contractual agreement. Anyway, as an exercise, one can simulated several inventory policies, to see if there is any improvement in performance indicators for the real system. Particularly, one can see that depending on the particular realization of the demand stochastic process, the amount of inventory that is maintained can increase seriously, and so, there will be some money invested in an asset that has a limited liquidity, and probably a rate of return lower than the one expected for the company. This will happen because the inventory being kept specifically as a consequence of contractual conditions, is not supporting the fulfill of demand variations.

5. Case modeling and discussion

A cash flow approach is used to model the performance of inventory policies in the system described. The cash flow is constructed in such a way that includes taxes expenses (a tax rate of 35% annual, in Colombian pesos, is used), so the evaluation is done by calculating the NPV after taxes. The system is decomposed in business days (360 days a year) for making calculations about inventory holding, while the cash flow is constructed for a year, decomposed in months. The revision period for inventory level is 1 month. Purchasing lead time is set up to 0.5 months. Initial inventory level used is 47 TN.

Three scenarios are considered for simulation: in the first one the amount of every order of raw material is 100TN, given the fact that there is a contractual arrangement; for the second one, standard formulation for estimating the maximum inventory level that is supposed to be used in an R,S system is calculated and used along the simulation process; in the third one, an arbitrary order amount is used, just like the case when market conditions affects the provisioning decisions. There is not a priori evidence that one of them is better than the other ones, for example, the standard formulation versus the ordering policies related to contractual conditions. Also, if some improvements are obtained using one or another, those improvements should be considered only for this particular exercise, since generalization requires a broader study.

5.1 Deriving the inventory policies using the usual approach

The mathematical formulation for calculating the maximum inventory (order up to level) level for the (R, S) control system can be reviewed in Ballou (1999). Assuming that a P2 service level is predefined and used (in this case it is equal to 95%), the following equations shows the calculations:

$$G_u(k) = \frac{DR}{\sigma_{R+L}}(1-P2) \qquad (1)$$

Where G_u stands for a special function of the normal distribution, used for accounting the expected stockouts on an inventory system when demand over lead time period plus the revision period is assumed to follow a normal distribution; D is the demand in units, R is the revision period, and σ_{R+L} is the standard deviation of demand over lead time (L) plus revision period (R). Using the equation (1) a numerical value is calculated for k, and in the case where the result is a negative quantity, then a value of k set up by managers is used. k is referred as a factor related to safety stock.

$$S = \overline{X}_{R+L} + k\sigma_{R+L} \qquad (2)$$

Equation 2 defines the calculation of maximum inventory level S. $\overline{X}_{R+L}$ stands for the average demand over a period made up of the sum of revision period R and lead time L. In this case the R parameter has been predefined to a 1 month. For the data set used in the case studied, the maximum level of inventory proposed for this standard formulation is 142 units (copper TN).

5.2 Understanding the basic idea of the VaR indicator

According to Jorion (1996), the VaR indicator makes an effort to consolidate into a single number the total risk exposures faced for a financial portfolio. The VaR calculates the maximum loses expected, or equivalent, the worse scenario for the portfolio's value, given a certain probability and a period of time. Generally speaking, if planning horizon is N period and α% is the confidence level, then the VaR indicator can be obtained as the looses for the (100-α) percentile, in the left tail, given the probability distribution for the changes in portfolio valuation for the next N periods. VaR can be seen as the answer for a single question: ¿how bad can the things goes on?. It is measured in currency units so it is easy to understand. Additional details on several methods to calculate the VaR can be reviewed in Pritsker (1996). Figure 1 illustrates the VaR concept in a graphical way. The shadowed area below the curve denotes the probability α%, whilst the VPN_α value correspond to the VaR, worse scenario expected over the VPN indicator given the confidence level.

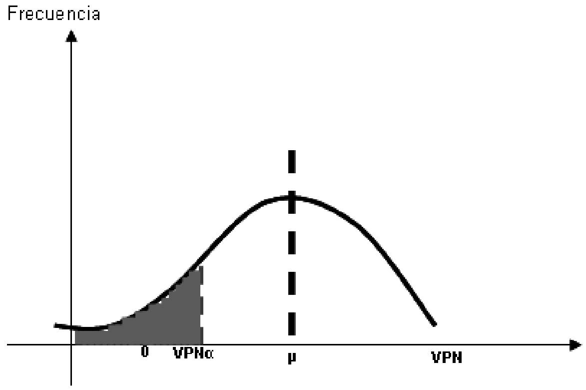

Figure 1. VaR over VPN in a graphical way

5.3 Results

Crystal Ball® software has been used for simulation process. Below are the outputs for three cases, as well as some descriptive statistics for the NPV indicator.

In every of the above figures the VaR indicator is calculated in a graphical an a numerical way. Since the indicator used is NPV, the VaR is calculated at the left tail of distribution. In each case 5% have been used as a confidence level. One can see that there is a inventory policy for which the VaR is minor than the other one, and so, the maximum amount of money that is supposed to be in risk is lower. That suggest that it is possible to try to find a value for the parameter S of the inventory policy, that minimizes the risk exposure of the company, due to variations in inventory holding policy. Although for this case the parameter R has been defined according to managerial issues, for example, a coordination strategy, it can also be included as a value that simulation can modify.

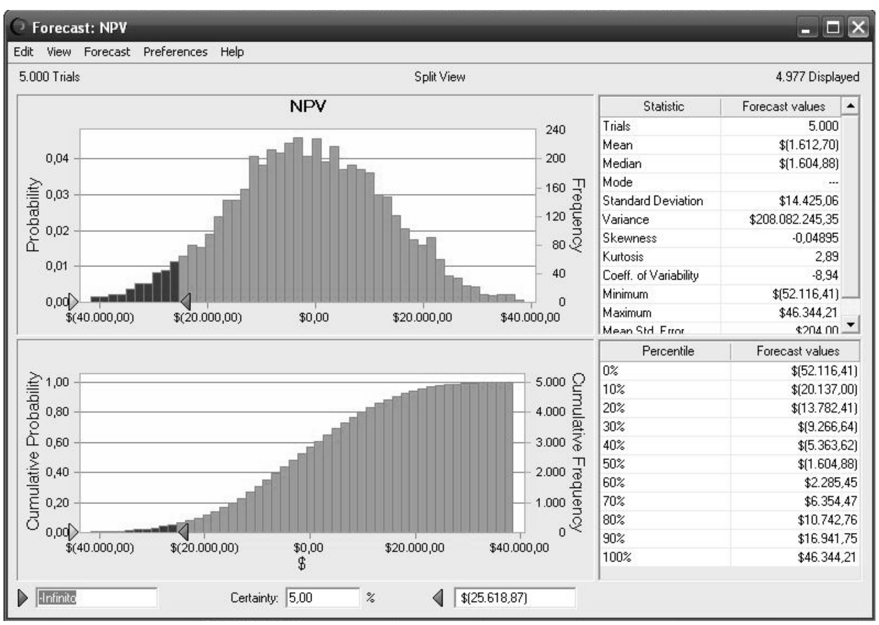

Figure 2. Outputs when each month an ordered for 100 TN is placed

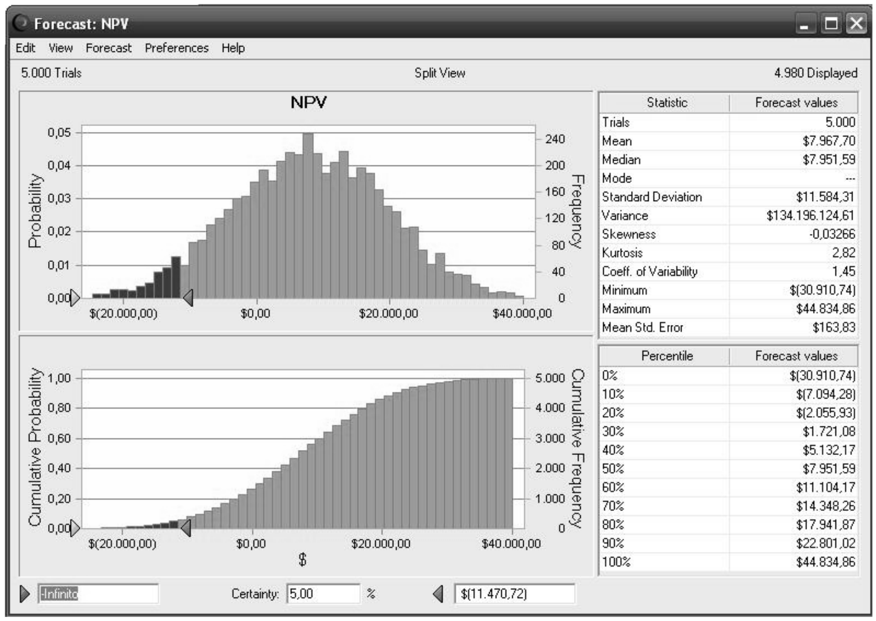

Figure 3. Outputs when the maximum inventory level used as goal in every order is 70 TN

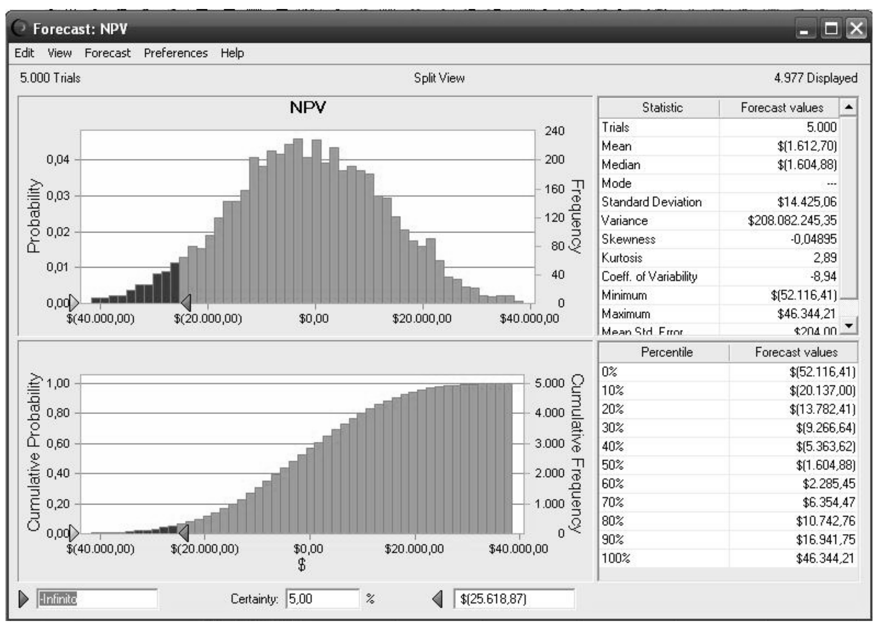

Figure 4. Outputs when the maximum inventory level used as goal in every order is 142 TN

The additional value of S that has been used as a policy for inventory management is 70 TN. Is an arbitrary value chosen to be lower than the amount that is supposed to be used due to contract arrangement, since the other value used, derived from standard formulation, turns out to be 142 TN, which is greater than the contractual amount.

*So far, we have not designed a formal proce*dure for finding an optimal policy with respect to the VaR indicator. What we can say is that the Figure 4 shows the output obtained when using an S parameter that has been calculated in the standar form, that is, assuming that the inventory system is evaluated by average cost indicator. That is the traditional approach, and one can see that using some other value as a parameter for the inventory policy, the system performance can be improved, in the sense of VaR reduction. This findings are in same direction that the ones mentioned in the section 3, preliminary research, some of them stated that when one includes the cost elements of an inventory system beyond the accounting point of view, including discount rates, for example, the optimal decisions derived can be wrong, an so do not reach optimality.

Simulation process is not designed for been able to find optimal solutions, and also, analytical handling of NPV functions in a direct way can be cumbersome. What it possible to do is to design several scenarios with values to the parameters that one think can be useful. That kind of procedure has not been implemented in this study, but seems a good point to start.

6. Conclusions

- It has been shown that VaR indicator can be used to measure the performance of inventory policies used in a manufacturing system. The discounted cash flow approach has been used to build and test a financial model from which is possible to calculated the NPV after taxes. It is possible to see that some inventory positions can lead the system to the exposition of a greater potential looses, that should always be avoided. One can also see that traditional selection of inventory policies derived from average cost minimization do not necessary reach to an optimum, when financial perspective is used over the system.

- Although no formal procedure is suggested for finding optimal policies, the simulation can be mentioned like a valuable tool for approaching this problem. Several works have shown that assumptions related to the normality of performance indicators is not often a good idea, and so, numerical computations are preferred for calculation indicators like VaR. The software that has been used for the present project is widely spread among several business, is easy to use, and can support the process of making better decisions. It is highly recommended that manufacturing systems used a financial approach for valuing its performance, since the financial perspective is a closer look to what really happen to the cash flow of real business.

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