International Journal of Management and Commerce Innovations ISSN 2348-7585 (Online)
Vol. 5, Issue 2, pp: (142-147), Month: October 2017 - March 2018, Available at: www.researchpublish.com

Role of Operations Research Techniques in Financial Market

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***Abstract*: The following research paper reviews the practice of operations research techniques in the financial market. The main problems faced in a financial market are individually identified and the ways OR techniques creates solutions for each issues are highlighted. OR techniques formulate such problems into mathematical problems and provide feasible solutions. Financial problems are numerical in nature with set objectives, having clear relationships between variables, thus it is appropriate for the application of OR techniques. With time OR has started playing a crucial role in the operations of the financial markets. This study will focus on various techniques like Monte Carlo Simulation, Decision trees, Game theory, Quadratic Programming Problem, Linear Goal Programming, Arbitrage Theory and many more techniques. Through the following research the increasing importance of these techniques in the financial market will be highlighted.**

***Keywords:* operation research techniques, financial problems, mathematical problems.**

1. INTRODUCTION

The objective of financial problem is usually to maximize profits or minimize risk, and the applicable variables are quantified, most of the times in monetary terms. Financial problems have an advantage that any solution generated by the mathematical model can be implemented without facing any limitation in terms of human behavior and choices that prevent the implementation of certain solutions. Along with the following advantage, it is also possible to gather information such as the historical data that is available from the market-recorded transactions and company records; abundant information related to the real time data of the market prices are also available to be used in the OR models. Financial Problems involve a large value of amount thus even a small modification in the quality of solutions can be beneficial to a greater extent. These issues have a tendency to iterate more than once, spreading the expenses of building up an OR model over abundant transactions. Thus the scale of the problem makes the development of the models more attractive than for one-off solutions.This paper consider some of the crucial problems faced in the financial market and assess the application of OR techniques by considering each solution for the appropriate problems.

2. RESEARCH METHODOLOGY

The rising importance of the operations research in the field of finance has led to various research papers available on the application of Operations Research in field of finance, engineering and mathematics. The research technique for the following paper has been more towards reviewing existing literatures and gathering qualitative information on the basis of historical data. Current OR models are assessed and their application is discussed in the following paper. The research paper identifies some of the main financial problem like funding decisions, economic application and other issues but doesn't get into corporate finance needs such as working capital management, inventory management, capital investment etc. Building new OR techniques for financial markets are out of the scope of paper. Further forecasting techniques are not considered in the paper. The objective of the paper is to highlight the ways OR technique is being currently being used in the financial market to make effective valuation and financial decisions.

The Valuation Strategy for Financial Instruments: when trading in financial markets, it is essential to value the instruments appropriately and the OR techniques have helped to create models that can efficiently determine the value of various instruments. In 1973, Fischer Black and Myron Scholes proposed Black-Scholes formula. The Black-Scholes Formula is a pricing model used to determine the theoretical value for European style call and put options. The closed form model depends on the accompanying six factors: unpredictability, kind of option, hidden stock value, time, strike cost and hazard free rate. The formula assumes that the underlying stock price follows a geometric Brownian motion with constant volatility. The model presumes stock prices follow a lognormal distribution. A lognormal distribution allows for stock prices distribution of between zero and infinity indicating no negative prices. The model presumes there are no transaction costs or taxes; the risk free interest rates are stable for all maturities period and there are no arbitrage opportunities. The key value of the Black Scholes Model is that it gives you a chance to compute an extensive number of option costs in a brief period. Yet, it cannot be used to accurately calculate the price options with an American-style exercise as it calculates the price only during the maturity date of the option. Cox, Ross and Rubinstein (1979) proposed Binomial model as method for the valuation of option. Through the following model, a tree of stock prices is created starting from the present till the maturity date of the option.At each stage it is presumes the underlying stock price will move in the upward or downward direction by a value calculated using fluctuation in the price and time to expiration. The tree denotes the possible path the price of the stock could cover during the duration of the option.The terminal value of the option is calculated at the end of the tree through intrinsic valuation. Any modification to stock prices at an ex dividend rate or Option prices (American Options) are adjusted in the calculation at the particular point of time. The Binomial model builds the same equation using computational algorithms whereas the Black-Scholes model builds it using analytical approach. But the following techniques can only be used for pricing options for which closed form of solution is readily available. OR techniques have shown a significant contribution in the pricing of more complex derivatives. Boyle (1977) introduced the Monte Carlo simulation as alternative to the Binomial model.Monte Carlo simulation concurrence rate is independent of the number of state variables while the Binomial model is growing in the number of state variables. MC simulation performs risk analysis by forming computer models for data with significant uncertainty in inputs. The payoffs are weighted by their risk neutral probabilities and then discounted back using the risk-free rate, letting the mean present value across all the sample paths to be computed to give the current price of the option (Boyle, Broadie and Glasserman, 1977). The simulation allows better estimation of the present value by repeating the calculation with the growth and the discount rate selected according to their probability distribution. Clewlow and Strickland (1998) and Hull (2000) point out that Monte Carlo Simulation generates high variances that lead to computation inefficiency. To overcome the extreme variances different diminishment strategies have been executed in the Monte Carlo evaluating techniques, for example, *antithetic variates, control variates, stratified and latin hypercube testing, significance inspecting and contingent monte carlo.* Quasi-Monte Carlo simulation has been further introduced as a modification of Monte Carlo simulation that has been applied to speed up the simulation.

Funding Decisions: OR techniques over a period have introduced mathematical models that meets the basic objective of any funding decision which is to maximize the returns on minimize the cost. (1983) Brick, Mellon, Surkis and Mohl developed bounded linear programming model to record the mix of debt-equity ratio for each period that maximizes the value of the firm. Kornbluth and Vinso (1982) created a model of the financial decision for a multinational company. It considered two objectives – accomplishing the desired debt/equity ratio in each geographical zone and minimizing the weighted average cost of capital. Another essential problem is selecting an investment option that is optimally allocating the investment resources among a set of assets. Harry Markowitz (1952), introduced the Markowitz portfolio theory which is the foundation of Modern portfolio Theory. According to the following theory portfolio theory can be defined in terms of mean and variance. For different choice of portfolio the investor will get different combinations of mean and variance. As an investor aims for maximizing its profits and minimizing risk one would choose a set where the mean is the highest and variance is the least. The borrowers to choose between alternative mortgages contracts have used decision tree. Through the decision tree the expected value and the variance for the following three mortgage contracts- fixed rate, variable rate and adjustable rate mortgages are calculated. Crane, Knoop and Pettigrew (1977) formulated a linear programming model to solve the problem of deciding bond maturity. The objective of the model was to achieve the minimum costs reflecting the interest rates payable on alternative maturities.

Application of Game Theory: Game Theory is the study of mathematical models of conflict and cooperation between intelligent and rational decision makers. Today game theory applies to a wide range of behavioral relations. Modern game

Theory began with the idea regarding the existence of mixed equilibrium in two-person zero –sum games and Prof. Jon Von Neumann gives its proof.

Game theory studies situations in which parties compete, and also possibly cooperate, to influence the outcome of the parties' interaction to each party's advantage. Application of game theory is seen in :

- Initial Public offering (IPO): Rock in his paper in 1986 explained under pricing occurred because of 2 groups of investors informed and uninformed. Informed will buy at market price meaning uninformed will get higher proportion of overpriced stocks. Rock suggested in order to induce uninformed to participate they must be compensated for buying the stock . Many theories followed after that: Weltch (1989) to truthfully induce investors to reveal their valuations, Benviniste and Spindt (1989)to deter lawsuits, Hughes and Thakor (1993) to stabilize prices

- Determination of success of tenders: Game theory helps to formalize intuition. Game theory works by obtaining a set of intuitions and counter intuitions and then refining them by modifying intuitions to make the set look more realistic.

- Explaining use of financial intermediaries: Game theory helps identifying yield when capital investment is known by two methods: monitoring (payment cost a certain cost {K} to monitor yield) and incentive contract . Papers by Stiglitz and Waltz (1981) showed an adverse selection model in which rationing credit is optimal. In 1984 Diamond published a paper that considers a model of delegated monitoring where banks have an incentive to monitor borrowers because otherwise they will be unable to pay off depositors.

- Capital structure: In 1977 Ross developed a Model where managers could signal the prospects of the firm to the capital markets by choosing an appropriate level of debt. This might act as a signal for bankruptcy. Myers in 1984 developed the pecking order theory where instead of using equity to finance the projects less information sensitive sources were used : retained earnings preferred over debt financing

- Stock Market: Investment counsellors working for brokerage firms develop trading strategies for stock market investments. Good strategies attract investments while poor discourage them. Example: Firm will need a strategy to deal with investments in a bull market and for bear market .The collective strategies of all investment counsellors comprise the investment services a brokerage firm offers to a potential investor. This process can be envisioned, as evolving sets of strategies were fitness is measured by the returns derived by using the strategy to make investment decisions. Stock market investment is naturally expressed as a game. The players are brokerage firms, which independently develop investment strategies. Strategies compete against each other in market place and receive payoffs in form of greater or fewer investor dollars depending on how well they perform (poor strategies loose investments as investors switch to better performing strategies). Hence stock market is essentially a zero sum game with strategies formed through competitive coevolution. In some games players make decisions based on historical data, which is common knowledge.

- Price Determination: Application of game theory in recent years , some of the decisions facing traders and market makers in financial markets have been analysed using game theory . These models typically involve one or more market makers and traders who maybe informed or uninformed and discretionary or non discretionary. Traders in stock markets seek to trade at the most attractive prices and large trades are often broken up into a sequence of smaller trades in an effort to minimize the price impact. This can be viewed as a strategic problem with the aim of devising a strategy for trading the block of shares. The initial trades influence the price of subsequent traders, and so executing the large trade at the lowest cost is a dynamic problem. Applied game theory of the situation where a company has two major shareholders and a large number of very small shareholders. This can be modelled as an oceanic game, in which the two largeplayers behave strategically while the many other small shareholders (the ocean) do not. This approach can be used to derive the highest price a large shareholder will pay in the market for corporate control

Economic Understanding: the base cost stream issue is a system display that holds a focal position among organizes streamlining models, since it incorporates such a wide class of applications. Like the most extreme stream issue, it considers move through a system with restricted bend limits. Like the most brief way issue, it considers a cost (or remove) for course through a circular segment. Like the transportation issue or task issue, it can consider various sources (supply hubs) and numerous goals (request hubs) for the stream, again with related expenses. Actually, each of the four of these issues is a exceptional instance of the unadulterated least cost stream issue. The single ware least cost stream issue is a standout amongst the most major models in arrange stream hypothesis. It is to locate an achievable stream of least

aggregate cost from an arrangement of supply hub to an arrangement of interest hub in a system with limit imperatives what's more, curve costs. This model can be utilized specifically in different genuine applications,which emerges in transportation, coordination, media transmission, organize plan, asset arranging, booking and numerous different businesses. Additionally, it frequently emerges as a sub issue in more unpredictable streamlining models, for example, multi-item stream issues. It can be had some expertise in to two different issues:

• If the limit requirement is evacuated, the issue is decreased to the briefest way issue.

• If the expenses are all inspire equivalent to zero the issue is lessened to the most extreme stream issue. There are two conceivable methods for defining the base cost stream issue comparing to the system models. These are summed up least cost stream issue furthermore, unadulterated least cost stream issue.

1.2.1 Generalized least cost stream issue

A summed up least cost stream issue is a summed up arrange display which characterized by a given arrangement of circular segments and a given arrangement of hubs, where each curve has a known limit and unit cost and every hub has an outside stream.

Numerical programming detailing

Let G = (N,A) be a coordinated chart comprising n =| N | hubs and m =| A | bends.

Each circular segment (I, j) 2 A has a related cost cij per unit stream on that bend. we accept that the stream cost is nonnegative that fluctuates straightly with the measure of stream. Each circular segment (I, j) 2 An additionally has a limit uij signifying the most extreme sum that can stream on the circular segment, a lower bound lij the base sum that must stream on the bend, and the pick up parameter gij speaks to additions or misfortunes.

The choice factors are: xij = the measure of course through circular segment I ! j

Minimize=

$$\sum_{(i,j)\in A} C_{ij}X_{ij}$$

Ross (1976a, 1976b) created the Arbitrage Pricing Theory (APT) y. It is a one-period show in which each financial specialist trusts that the stochastic properties o profits of capital resources are predictable with a factor structure. Ross contends that if harmony costs offer no arbitrage openings over static arrangement of the benefits, at that point the normal profits for the advantages are around directly identified with the factor loadings. (The factor loadings, or betas, are corresponding to the profits' covariance with the variables.) The outcome is expressed in Section 2. Ross' (1976a) heuristic contention for the hypothesis depends on the prevention of arbitrage. This instinct is portrayed in Section 3. Ross' formal verification demonstrates that the direct valuing connection is a fundamental condition for balance in a market where specialists boost certain sorts of utility. The ensuing work, which is studied underneath, gets either from the presumption of the prevention of arbitrage or the harmony of utility-expansion. A direct connection between the normal returns and the betas moment add up to an identification of the stochastic rebate factor (SDF). Sections 4 and 5, individually, audit this writing. The APT is a substitute for the Capital Asset Pricing Model (CAPM) in that both declare a direct connection between resources' normal returns and their covariance with other arbitrary factors. (In the CAPM, the covariance is with the market portfolio's arrival.) The covariance is deciphered as a measure of hazard that financial specialists can't stay away from by diversification. The incline coefficient in the direct connection between the normal returns and the covariance is deciphered as a hazard premium. Such a connection is firmly attached to mean-fluctuation efficiency, which is looked into in Section 6. Area 6 likewise calls attention to that an observational trial of the APT involves a system to distinguish at any rate a few highlight of the fundamental factor structure. Just expressing that some accumulation of portfolios (or even a solitary portfolio) is mean-fluctuation efficient in respect to the mean-change boondocks spread over by the current resources does not constitute a trial of the APT, on the grounds that one can simply find a mean-difference efficient portfolio. Subsequently, as a trial of the APT it isn't sufficient to simply demonstrate that an arrangement of factor portfolios satisfies the direct connection between the normal return and its covariance with the components portfolios. A portray of the observational ways to deal with the APT is offered in Section 7 though Section 8

depicts different methodology to recognize the basic components. The vast number of variables proposed in the writing and the assortment of measurable or impromptu methods to find them show that definitive knowledge on the point is as yet absent. Finally, Section9 studies the utilizations of the APT, the most conspicuous being the assessment of the execution of cash administrators who effectively change their portfolios. Unfortunately, the APT does not necessarily preclude arbitrage opportunities over dynamic portfolios of the existing assets. Therefore, the applications of the APT in the evaluation of managed portfolios are contradictory at least in spirit to the APT, which obtains price restrictions by assuming the absence of arbitrage. In addition to its traditional role of improving the quality of decision making, OR can also help in trying to understand the economic forces shaping the finance sector. Financial innovation may occur when there is an exogenous change in the constraints or in the costs of meeting existing constraints. Using a linear programming model of a bank, Ben-Horim and Silber employed annual data to compute movements in the shadow prices of the various constraints. They suggested that a rise in the shadow price of the deposits constraint led to the financial innovation of negotiable CDs. Arbitrage Pricing Theory (APT), which can be viewed as a generalization of the Capital Asset Pricing Model (CAPM), seeks to identify the factors which affect asset returns. Most tests of the APT use factor analysis, and have difficulty in determining the number and definition of the factors that influence asset returns

Imperfection in Financial Market: while ideally markets could behave as perfect markets where there is no need for government intervention, Financial Markets today function in an imperfect state and are constantly optimized by the trading being done on real-time in the market. This also occurs when individual(s) have undue influence over the market (hegemonies, monopolies, and coalitions) and when there is a lack of a state of perfect information amongst the market participants.In reality, all markets are ultimately imperfect. This is because in theory there can never be a state of homogeneity among the market actors. At the very least there is a difference in latency times of different trades being made in the market by different traders leading to the fastest trader maximizing gains. For Example: High Frequency Trading, Algo-Trading. Also, the new information is not transmitted perfectly in the market, which in theory would lead to a set of chain reactions in the market at an infinite speed.Although the assumption of perfect markets helps in arriving at various conclusions. That rationale is used in coming up with prices, incentives and economic drivers. It would however be imprudent to derive the same reasoning of perfect competition into real-life scenarios. At the outset we can see logical inconsistencies, for example in any perfectly competitive industry it would be impossible to achieve equilibrium from any other position than the ones meeting the set criteria (price, supply, unlimited buyers and sellers, homogeneity et cetera). Thus, perfect competition can never ideally exist.So, in reality one cannot expect a financial market to have these characteristics. However, today we see markets, which have varying degrees of imperfection/ perfection. They are characterized by their varying degrees of efficiencies and level of dynamism.

3. CONCLUSIONS

Operations Research has been widely used in the financial markets through various techniques and mathematical programming. Techniques like Black Scholes Model, Binomial model, and Monte Carlo simulation have been effectively used in valuation options from European option to American bonds. The techniques have been modified over time to reflect various requirements from the maturity date to dependency on the underlying variables. Similarly mathematical programming's like linear programs were employed to attain the desired debt equity combination aiding in minimizing the overall cost of capital. To consider the right portfolio modern portfolio techniques have been introduced over the time that considers the two objectives of an investor- maximize return and minimize risk. Decision tree are used by borrowers to decide on the mortgage contracts consider the three alternatives interest rates. Financial Markets are further efficiently analyzed through game theory to plan effective strategies in order to retain the control over the company considering the trading frequency in the financial market. Thus it can be observed that over the generation OR techniques have improved the way financial markets have functioned, with the rising development in technology it has created a platform for the investors to evaluate their financial decisions from all perspective considering all the possible situations through probabilistic models. Queuing theory another effective OR technique can be utilized in the financial market and should be further explored. Finance theories have also contributed in the field of operations research as they create the need to build and modify OR techniques. It can be stated that the relation between finance and operations research is two-way; as more innovative technology will be introduced and improvements will be made in the availability of real time data the greater will be the chance for the OR techniques to play a crucial role in the financial markets.

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