Finance Applications of Game Theory and Behavioral Finance: A Review and Synthesis

Onuegbu Onyekachi; Iwedi Marshal; Igbanibo Dumini Solomon

1Department of Banking and Finance Michael Okpara University of Agriculture, Umudike Abia State, Nigeria
2&3 Doctoral Students Department of Banking and Finance Rivers State University of Science and Technology, Nkpolu Port Harcourt, Nigeria.

Abstract
This paper briefly reviews and synthesizes the finance applications of game theory and behavioral finance. It demonstrated how game theoretic techniques have allowed insight into these puzzles with higher order beliefs, informational cascades and heterogeneous prior beliefs. It has also helped in resolving the apparent empirical anomalies in traditional finance theories using the two building blocks of behavioral finance.

Keywords: Finance, Game Theory, Behavioral Finance, Limit to Arbitrage, Psychology Bias

1. INTRODUCTION
Basically finance is concerned with how the savings of investors are allocated through financial markets and intermediaries to firms, which use them to fund their activities (Allen & Morris 1998 and Arias 2010). In broad term, finance can be broken down into two domain of knowledge. The Asset Pricing: This is interested with the decisions of investors. Corporate Finance: This deals with the decisions of firms. However, this paper will focus on corporate finance domain of knowledge and the finance application of game theory with the view of unveiling certain behaviors that are regularly witnessed. The traditional finance theory/thinking relies on assumptions of certainty, complete knowledge and market efficiency and in this context financial decisions are relatively straight forward.

1.1 The Capital Assets Pricing Model (CAPM)
In finance, the capital asset pricing model (CAPM) is used to determine a theoretically appropriate required rate of return of an asset, if that asset is to be added to an already well-diversities portfolio, given the assets non-diversifiable risk. The model takes into account the asset’s sensitivity to non-diversifiable risk (also known as systematic risk or market risk), often
represented by the quantity beta (β) in the financial industry, as well as the expected return of the market and the expected return of a theoretical risk-free asset. CAPM “suggests that an investor’s cost of equity capital is determined by beta”. The CAPM was popularized by Jack Treynor (1962), William Sharpe (1967) John Lintner (1965) and Jan Mossin (1966). The capital asset pricing model (CAPM) is obtained as:

\[ E(R_i) = R_f + B_i (E(R_m) - R_f) \]

Where:
- \( E(R_i) \) is the Expected Return on the Capital Asset
- \( R_f \) is the Risk-Free Rate of Interest
- \( B_i \) (the beta) is the Sensitivity of the Expected Excess Asset Returns to the Expected Excess Market Returns.
- \( E(R_m) \) is the Expected Return of the Market
- \( E(R_m) - R_f \) is the Risk Premium.

Despite being based on the very strong assumptions of mean variance preferences and homogeneity of investor beliefs, the CAPM was an extremely important development in finance. It not only provided key theoretical insights concerning the pricing of stocks but also leads to a great deal of empirical testing whether these predictions held in practice. Early test by Fama and Macbeth (1973) provided some support for the model. But however, subsequent tests using more sophisticated econometric techniques have not been so encouraging. Ferson (1995) contains a review of these tests.

1.2 The Efficient Market Hypothesis

In finance, the efficient-market hypothesis (EMH) asserts that financial markets are “informationally efficient”. In consequence of this, one carried consistently achieve returns in excess of average market returns on a risk-adjusted basis, given the information available at the time the investment is made. The EMH independently developed by Paul, A. Samuelson and Eugene, F. Fama in the (1960s), this idea has been applied extensively to theoretical models and empirical studies of financial securities prices, generating considerable controversy as well as fundamental insights into the price discovery process.

In a well-known study, Fama (1970) argued that the balance of the evidence suggested markets were efficient. Furthermore, Fama (1991) continued to argue that by and large markets were efficient despite the documentation of
many anomalies during the interfering period. The most enduring critique come from psychologists and behavioral economists who argue that the EMH is based on counterfactual assumptions regarding human behavior, that is, rationality.

Empirical analyses have consistently found problems with the EMH, the most consistent being that stocks with low price to earnings outperform other stocks (Fama and French, 1992), Rosenberg, Reid and Lanstem, (1985), Sanjoy, 1977 and Francis 1968). Alternative theories have proposed that cognitive biases cause these inefficiencies, leading investors to overpriced growth stocks rather than value stocks (Fox 2002). Although the efficient market hypothesis has become controversial because substantial and lasting inefficiencies are observed, Beechy et al. (2000) consider that it remains a worthwhile starting point. Recent advances in evolutionary psychology and the cognitive neuroscience may be able to reconcile the EMH with behavioral anomalies.

1.3 Modigliani and Miller Theorems
The firm’s financial decisions are considered as the second important area of finance. These decisions include the choice between debt and equity and the amount to be paid out as dividend. Modigliani and Miller (1958) and Miller and Modigliani (1961) work in this area showed that with perfect markets (i.e., no frictions and symmetric information) and no taxes the total value of a firm is independent of its debt/equity ratio. Similarly they demonstrated that the value of the firm is independent of the level of dividend. In their framework it is the investment decisions of the firm that are important in determining its enterprise value. They went further to explain that the value of the firm depends on the earnings and risk of its assets (business risk) rather than the way in which assets have been financed. (Pandey 2005). The importance of the Modigliani and Miller theorems was not as a description of reality. Instead it was to stress the importance of taxes and capital market imperfections in determining corporate financial policies. Incorporating the tax deductibility of interest but not dividends and bankruptcy costs lead to the trade-off theory of capital structure. Some debt is desirable because of the tax shield arising from interest deductibility but the costs of bankruptcy and financial distress limit the amount that should be used. Within the MM framework other corporate financial decisions also do not create value
except through tax effects and transaction cost. Although theoretical insights are provided, the theories are not consistent with what is observed in practice.

1.4 Continuous Time Finance Model
This model was developed in a series of papers by Merton (1969, 1971 and 1973) and culminated in his development of the intertemporal capital asset pricing model (ICAPM). The relationship between continuous time models and equilibrium model was considered by Harrison and Kreps (1979) and Duffic and Huang (1985). Repeated trading allows markets to be made effectively complete even though there are only a few securities. Continuous time finance model is use for the pricing of derivative securities such as options.

2. The Game Theory and its Applications to Finance
The Game theory has made great strides in explaining many of the observed phenomena falling under corporate finance. We start with how different game theory models can be applied to more accurately explain observed financial decisions dealing with capital structure, corporate acquisition, Initial Public Offerings (IPOs) financial intermediation and subsequently consider its role in asset pricing.

2.1 Application One: Corporate Acquisition/Takeover Bids
Game theory can also be applied to explain what is observed in the course of many corporate acquisition if markets are efficient than one would expect a company to pay fair value when acquiring another company, however in many instances the acquirer pays a large premium to buy the other company. In 1986 Shleifer and Vishny provide one explanation of this phenomenon, the free rider problem. They pointed out that if the raider is a large shareholder aid, if permitted to profit from secretly purchasing a proportion of shares prior to the tender offer, the free-rider problem can be solved even without dilation. The tender offer can be profitable because the raider can profit on his own shares even if he offers $P > V + X$ and losses on the tendered shares. One of the concepts behind efficient markets is the market for corporate control. The market for corporate control says that in order for resources to be run by the most able and competent managers. One way to achieve this is through corporate acquisitions. A company is not likely to purchase another company unless it feels it can run it better than the current management. This can be
through new management or synergies that occur because of the operational efficiency of the combined firms. Shareholders of the company to be acquired realize that the new management will run in their company more efficiently and thus their shares will be worth more than before the purchase. Since shareholders will be able to benefit from the improvements implemented by the new management they have an incentive to hold out and say no to the bid. They will only be willing to tender their shares if the offer price fully reflects the value under the new management. Therefore, a bidding firm cannot make a profit from tendering for the target firm and in truth, after the costs of acquiring information in preparation for the bid, the bidding firm will make a loss.

The second puzzle associated with corporate takeovers that has been documented is the fact that bidding in takeover contests occur through several large jumps rather than many small ones. The logic behind such behavior as reported by Fishman in 1988 is relatively straightforward. Observing a bid alerts the market to the potential desirability of the target. If the initial bid is low, a second bidder will find it worthwhile to spend the cost to investigate the target. This second firm may then bid for the target and push out the first bidder or force a higher acquisition price.

2.2 Application Two: Initial Public Offerings (IPOs)

Initial Public Offerings (IPOs) have long been known to provide a significant positive return in the initial day of trading. Thus occurrence directly conflicts with the theory of market efficiency because the companies should be fairly valued at their IPO and any return in the initial days should be minimal. In 1986 Rock explained that this phenomenon was due to adverse selection between informed buyers and uninformed buyers. The informed buyers know the true value of the stock and will only purchase shares at or below its true value. The implication of this is that the uninformed buyers will receive a high allocation of overpriced shares since they will be the only people in the market when the offering price is above the true value. Knowing this, uninformed buyers would be unwilling to purchase the stock, forcing the informed buyers to hold onto the stock because there is no one they can sell it to. Therefore, to induce the uninformed to participate they must be compensated for the overpriced stock they end up buying. One way to do this is to underprice the stock on average. This means that on average the uninformed will
buy a stock that started out undervalued and thus they are still able to buy the stock at or below its true value. Since all investors know that an IPO will likely be underpriced they all try to buy the stock as quick as possible creating a demand for the stock that results in substantial price gains in the initial days of trading. Another interesting implication of IPOs pointed out by Ritter in 1991 is the fact that while they experience high returns in the short run they typically under-perform the market in the long run. One argument for this behavior is that the market for IPOs is subject to fads and that investment banks underprice IPOs to create the appearance of excess demand. This leads to a high price initially but subsequently under performance, therefore companies with the highest initial returns. There exists evidence of this in the long run.

2.3 Application Three: Capital Structure

This is a game under the assumption of symmetric information. The main focus of the game is on commitment rather than on information transmission. In the game, each firm purposely risks bankruptcy to create a conflict of interest between debt and equity that increases its aggressiveness in seeking market shares. The outcome is worse for the firms. Capital structure deals with the firm’s decision to raise funds through debt versus equity and what ratio of debt to equity should the firm maintain. Modigliani and Miller (1958) showed that in perfect capital markets (i.e no frictions and symmetric information) and no taxes a firm could not change its total value by altering its debt/equity ratio, thus capital structure is irrelevant. However, in the real world, capital structure is carefully thought about by every company and it is in fact not irrelevant because taxes do exist and capital markets are not perfect. In Nigeria, interest paid by a company is a tax-deductible expense. This tax shield creates an incentive to take on debt. Modigliani and Miller corrected their original model to include corporate income taxes showing that a firm could increase its equity, or shareholder value, by taking on debt and taking advantage of tax shields. Their model then showed all firms stood to gain the most if they were 100% debt financed, however this is not observed in reality. Different game theory models have been used to explain the actions of managers in determining their company’s capital structure, the most influential deals with the signaling effects attributed to debt versus equity financing.

Myers and Majluf (1984) developed a model based on asymmetric information
that insists managers are better informed of the prospects of the firm than the capital markets. If management feels that the market is currently undervaluing its firm’s equity then it will be unwilling to raise money through an equity issue because it will be selling the stock at a discount. On the other hand, management might be eager to issue equity if it feels its stock is overvalued, because it will be selling its stock at a premium. Investors are not dull and will predict that managers are more likely to issue stock when they think it is overvalued while optimistic managers may cancel or defer issues. Therefore, when an equity issue is announced, investors will mark down the price of the stock accordingly. Thus equity issues are considered a bad signal, even companies with overvalued stock would prefer another option to raise money to avoid the mark down in stock price. Firms prefer to use less information sensitive sources of finds. This leads to the pecking order of corporate financing refrained earnings are the most preferred, followed by debt, then hybrid securities such as convertible bond and lastly equity.

Agency cost is the second application of game theory to capital structure Jensen and Meckling (1976) described two kinds of agency problems in corporations.

1. Between equity holders and bond holders
2. Between managers and equity holders

Financially sound company would not have the agency problem because equity holders would not have the agency problem because equity holders stand to lose more from risky projects when the company is not in risk of going bankrupt, and thus want to avoid them along with bondholders.

2.4 Application Four: Financial Intermediation

In most models, the players begin with symmetric information, but they know that some players will later acquire an informational advantage over the others. The model that I am going to use here is an example of theory-based institutional economics. The purpose of this is to show that:

1) An intermediary is useful only if there are many investors and many entrepreneurs.
2) Incentive contracts have economies of scales compared to monitoring.

Diamond (1984) provides a model of financial intermediaries, so that M risk-neutral investors wish to finance N risk-neutral firms. Each entrepreneur has a project that requires 1 unit in capital and yield Q level of output, where Q is initially
unknown to anyone. If Q < 1, the entrepreneur genuinely cannot repay the investors, but the problem is that only he, not the investors, will observe Q, so they cannot validate his claim Q<1. The investors must rely on one of two things to ensure the truth: namely monitoring or incentive contract. Under a monitoring scheme, each investor incurs a cost C to observe Q, which makes it a contractible variable, on which payment can be made contingent. The entrepreneur suffers a dissipative punishment S(X) under the incentive contract if he repays X. The cost of monitoring is MC, while the expected cost of an incentive contract is ES. In the absence of an intermediary, if ES<MC, the incentive contract is preferred. The underlying idea behind the financial intermediary is to eliminate redundancy by replacing M. individual monitors with a single monitoring agency. The intermediary itself requires an incentive contract, at cost ES. To justify its existence, it should spread this cost over many entrepreneurs. If N=1, the intermediary incurs a cost of C for monitoring and ES for its own incentive, whereas a direct investor-entrepreneur contract would cost only ES. In the above scheme, while information is still symmetric, the institution assumes a particular form to avoid information problems by contracting. The main driving force behind the existence of financial intermediaries is the asymmetric information which opens doors for a much wider application of game theory. Reputational issues on the part of borrowers becomes very important and were first analyzed by John and Nachman (1985) in a two-period model. They depicted, in sequential equilibrium, a problem in which agency debt can be decreased when compared with a single-period model. Diamond (1989) uses a somewhat similar model in which borrowers deal with banks over more than one period and have an incentive to build a reputation for repaying loans. This provides a partial improvement of the problem in one-shot games in which the borrower prefers risk investments than the lender would like.

3. Models of Information and Beliefs

Recent developments in game theory have provided powerful new techniques that have the potential to explain many important financial phenomena. We will be reviewing three lines of research and their implications to finance in this section.
3.1 Higher Order Belief

Many economic and financial problems are naturally modeled as a game of incomplete information, where a player’s pay off depends on his own action, the actions of others and some unknown economic fundamentals. Rational behavior in such environment clearly depends on a player belief about economic fundamentals, but it also depends on higher order beliefs i.e. player beliefs about other player beliefs, and so on. Conventional wisdom holds that such higher order beliefs may play an important role in some economic phenomena. It is reported that following the Asian crisis some of the investors who withdrew their capital from Brazil, did so not because they overestimated the economic linkages between Asia and Brazil, but because they thought others might do so. It is reported that negative shocks to some hedge fund portfolios led some lenders to make excessive margin calls and seek to liquidate collateral, not because the fund was insolvent, but because they thought that other lenders might think so, and the had an incentive to get out early. It is reported that apparently irrelevant news about the economy leads some firms to reduce their investments (and thus to recession), not because they think that the new is relevant, but because they think others may think so. It is reported that some investors are currently paying inflated prices for internet stocks not because they believe that others believe so, and therefore there are short run speculative profits to be made.

Recent works by Shim and Morris (1999). He argued that it should be possible to take higher order beliefs seriously in applied economic analysis, exploiting the insights of the theoretical literature on higher order belief in game theory. One fruitful way of doing so is to consider global games models, first studied by Hans Carlsson and Eric Van Damme. Here it is assumed that each agent observes the true economic fundamental with a small amount of noise. This in turn implies that each agent has a small amount of uncertainty about what others believe and about what others beliefs about him. This simple information structure generates a rich structure of higher order beliefs where common knowledge of fundamentals would have allowed multiple equilibrium.

3.2 Information Cascades

There is now substantial evidence that financial market do not react to information exactly as suggested by the efficient market hypothesis. Consequently,
a number of studies have asked the question “how can this be explained”? Initially, one of the main explanations was that exogenous institutional imperfections, such as transaction costs are the cause. This type of explanation is now being replaced by behavioral ones, which focus on exactly how agents process information. The idea in this term paper is that agent’s respond not only to their own private information, but also to the information which they infer other agents have. The inference is made on the basis of the actions which other agents are seen to take Skerratt (2000).

There is a model to explain why groups of people sometimes converge upon poor decisions are prone to fads, even though they can discuss the outcomes of their choices. Models of informational herding or cascades have examined how rational individuals learn by observing predecessors actions and show that when individuals stop using their own private signals, improvement in decision quality cease. A literature on word-of-mouth learning shows how observation of outcomes as well as actions can cause convergence upon correct decisions.

However, the assumptions of these models differ considerably from those of the cascades/herding literature. One major weakness of the informational cascade argument is that it release on action sits being too coarse to reveal private information (Lee 1993). There are some contexts where this assumption is natural: for example, investors’ decisions whether to subscribe to initial public offerings at a freed offer price (although even then the volume demanded might reveal information continuously). But once prices are endogenized, the (continuum) set of possible prices will tend to reveal prices.

3.3 Heterogeneous Prior Beliefs

Heterogeneity arises because traders have different distribution assumption about an informed trader’s private signal, that is to say traders agree to disagree with the precision of the signal. The “No Trade theorems in various guises have established that when agents share the same priors beliefs, they will not trade for purely informational reasons, even in the presence of asymmetric information. It is assumed that all differences in beliefs are the result of differences in information, not differences in prior beliefs.

However, it does not matter if differences in beliefs are explained by different information or difference in priors. In his insightful paper Linter (1969) introduces a
dynamic model with heterogeneous beliefs and assuming, as he did, that investors do not learn prices—the origin of their differences in beliefs did not matter. It is only once it is assumed that individual learn from others action that the distinction becomes important. It was exactly when game theoretic and information theoretic issues were introduced in finance that the distinction was emphasized. Lots of literatures have studied the behaviours of irrational traders and the influences to the market. Odean (1998) presents three different markets structure two of which examine price-taking overconfident informed traders and one which looks as Kyle (1985) getting.

Kyle and Wang (1997) and Wang (1997) consider the case of heterogeneous prior beliefs. The former considers heterogeneous prior beliefs in their study of the survival of irrational traders in a duopoly context. While the later examine the implication of overconfident for delegated fund management in both learning and evolutionary game models. Harris and Raviv (1993) and Wang (1998) use heterogeneous prior beliefs to explain the enormity of volume traded each day. Specifically, Wang (1998) extends the model of Kyle (1985) by incorporating heterogeneous prior beliefs, He finds that in equilibrium, the informed trader, facing both asymmetric information and heterogeneous prior beliefs, smoothies out his trading on asymmetric information gradually over time, but concentrates his entire trading on heterogeneous beliefs toward the last few periods.

4. Resolving the Anomalies in Traditional Finance Thinking via Behavioral Finance

According to Thaler and Barberis (2002), behavioral finance has two building blocks:

4.1 Market Inefficiency (Limits to Arbitrage)

Limits to arbitrage seek to explain the existence of arbitrage opportunities which do not quickly disappear. It is associate with arbitrageurs co-existing with not-fully rational investors in the market and themselves not being able to profit from market dislocations.

4.2 Cognitive Psychology

Cognitive refers to how people think. There is a huge psychology literature available revealing that people make systematic errors in the way that they think
like overconfidence, representatives, putting too much weight on recent experience, anchoring etc. The field of behavioral finance uses this body of knowledge in building models which closely and efficiently explains the market and economic agents. Behavioral finance uses models in which some agents are not fully rational, either because of preferences or mistaken belief (Ritter, 2003). Understanding the existent of arbitrage opportunities, although theoretically counterintuitive, is not enough to make sharp predictions. Behavioral finance scholars often need to specify the form of the agent’s irrationality. This is related to how they misapply Bayess law or deviate from the Subjective Expected Utility Theory. In order to specify the type of irrationality, scholars have turned to experimental evidence compiled by cognitive psychologists on the biases that arise when people form beliefs and on the people’s preferences or on how they make decisions given their beliefs (Thaler and Barberis 2002).

4.3 Limits to Arbitrage
Mispricing of securities are common, but it is difficult to reliably make abnormal profile from these mispricing. In a market with not fully rational and rational agents, rational investors from influencing security prices by trading mispriced securities through a process called arbitrage. Therefore in an efficient market, there should be no arbitrage opportunities because competition will drive prices to their correct values. However, if non rational investors predominate in the market, it does not follow that prices in the financial market will fully reflect all the available information and this is equivalent to arguing that there will be arbitrage opportunities, (Herschberg, 2012).

In the traditional finance paradigm, arbitrage should be riskless and arbitrage opportunities must not exists. However, scholars have found strong evidence to assert the opposite. Arbitrage is generally risky and limited. In fact, there are situations where arbitrage opportunities exist but do not quickly disappear. This is known in the literature as limits to arbitrage and this is credited to Shleifer and Vishny, (1997). Situations in which there is a limit to arbitrage fail to be explained by classical finance theory and can be better understood using behavioral finance.

4.3 Psychological Biases
So many patterns regarding how people behave have been documented by cognitive psychologist. Some of these patterns are discussed below:

**Overconfidence:** There is a considerable evidence substantiating the proposition that people are unduly optimistic about their abilities and while making judgment (Odean, 1998). According to Ritter (2003), people their overconfidence in a number of ways. One example is too little diversification, it is the tendency of the people to invest a large amount of money in what is one familiar with. As a result, people invest in fundamentally lousy local companies even though this is bad from a diversification point of view. Barber and Odean (2001) found that the more people traded, the worse they did on average men traded more, and did worse than women investors. This is primarily because of the fact that men are more overconfident than the women.

**Framing:** Framing refers to the way a problem is posed for the decision maker. In many actual choice contexts the decision maker also has flexibility in how to think about the problem. For example, restaurants may advertise “early-bird” specials or “after-gym” discounts but they never use Peak-period “surcharges.”

**Mental Accounting:** The process of formulation of problems or actions with probabilities of different outcomes is called mental accounting. Individuals allocate wealth to separate mental compartments and ignore fungibility and correlation effects. One important feature of mental accounting is narrow framing, which is the tendency to treat individual’s gambles separately from other portions of wealth.

**Self–Attribution Bias:** When people attribute successful outcomes to their of skill and sound judgement and blame external causes for unsuccessful outcomes rather than on their own ineptitude, they in fact indulge in self-attribution bias. For example, investors might become overconfident after several quarters of investing success (Gervais and Odean, 2001).

**Anchoring:** When things change, people tend to be slow to pick up on the changes. In other words, people „anchor” too much on the initial or previous value (Barberis and Thaler, 2003). This can result into the investor believing that the stock to trade in a defined range.

**Disposition effect:** Shefrin and Statman (1985) found that investors are reluctant to sell assets trading at a loss relative to the price at which they purchased, a
phenomenon labeled the “disposition effect”. Odean (1998) finds that the individual investors in his sample are more likely to sell stocks which have gone up in value relative to their purchase price, rather than stocks which have gone down. Grinblatt and Han (2001) argue that the investor behavior inherent in the disposition effect may be behind a puzzling feature of the cross-section of average returns, namely momentum in stock returns.

**Heuristics:** Rules of thumb make decision making easier. However, they can sometimes lead to biases. The latter results into sub-optimal investment decisions. Benartzi and Thaler (2001) have documented that many people follow the 1/N rule.

**Representativeness:** People tend to put too much weight on recent experience. Representativeness can also arise in the guise of the “law of small numbers” whereby investors tend to assume small sample represents the properties of population. This error leads to investors picking hot stocks and to avoid stocks which have poorly performed in the recent past. This phenomenon could provide explanation for investor overreaction (DeBundt and Thaler, 1985) Kahneman and Tversky (1974) show that when people try to determine the probability that a data set A was generated by a model B, or that an object A belongs to a class B, they often use the representativeness heuristic. To illustrate, Kahneman and Tversky present this description of a person named Linda: Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations. When asked which of “Linda is a bank teller” (statement A) and “Linda is a bank teller and is active in the feminist movement” (statement B) is more likely, subjects typically assign greater probability to B. This is, of course, impossible. Representativeness provides a simple explanation.

**5. Conclusion**

In summary, the field of finance was reluctant to accepting the view of psychologists who proposed the behavioral finance model. Indeed, the early proponents of behavioral finance were regarded as heretics. As the evidence of the influence of psychology and emotions on decisions became more convincing, behavioral finance has received greater acceptance.
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