

A game theory formulation of decision making under conditions of uncertainty and risk

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ABSTRACT

A game setting is developed for decision making under conditions of uncertainty and risk for a general class of problems. The methodology is illustrated using assumptions governing future oil prices and environmental degradation to evaluate long term investment alternatives.

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1. Introduction/outline

The essence of a decision is the decision maker's personal balance of expected payoff and risk. A game theory formulation of decision making under conditions of uncertainty and risk, made possible by an appeal to the Central Limit Theorem, allows us to extend our basic understanding of decision making to a large class of complex decision problems with time as an independent variable.

In general, the decision maker plays against NATURE in a single move game. At the time the decision maker moves, NATURE's time dependent strategy is hidden forcing the decision maker to consider NATURE's strategy as uncertain. The formulation presented here maintains a distinction between uncertainty modeled without assuming a distribution and risk arising from quantifiable random variability, i.e., with a distribution.

A standard definition of game theory:

"Game theory is the study of the ways in which strategic interactions among rational players produce outcomes with respect to the preferences (or utilities) of those players, none of which might have been intended by any of them." (Stanford Encyclopedia of Philosophy)

provides motivation for our development and indicates the hopes we have for its application.

As an illustrative example, we will demonstrate how assumptions governing future oil prices and environmental degradation can be used to evaluate long term investment alternatives in a game setting, supporting strategic thinking in a real world problem scenario. We are presenting a complete decision methodology. Using the example, we will show how easily and transparently the modeling and decision methodology can be implemented.

Outline of the paper: Section 2. An introduction to the problem of evaluating long term investments in a decision environment of increasing oil prices and environmental degradation. This decision problem both motivates and illustrates our modeling/decision methodology.

Section 3. We are faced with two tasks: making sense of this unexplored complex investment environment, i.e., constructing meaningful models of the decision environment accounting for what we know, what we are willing to assume, and what is unknown, and developing a rational decision methodology based on the models. In Section 3 we develop a family of investment models.

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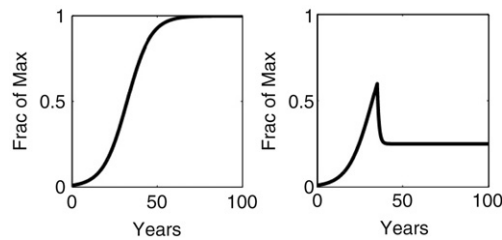


Fig. 1. The two graphs represent possible scenarios for future oil prices (or measures of environmental degradation). In the first scenario social change would be incremental. In the second, at some point change would be abrupt, the system would bifurcate.

Section 4. In this section we develop a family of general decision models. Basically, we introduce a two person game with players NATURE and PLAYER. NATURE's strategies are future oil prices and environmental degradation. PLAYER's strategies are rational investment decisions. We provide a complete computational example illustrating the construction of the decision models.

Section 5. We introduce a decision methodology which is an extension of multi-criteria decision analysis, replacing random criteria values with deterministic surrogates specifying risk. The criteria and surrogates are functions of the uncertainties. The decision goal is a balance of expected payoffs and risk.

Section 6. In the concluding remarks we address questions of more than two uncertainties and more than one criteria for evaluating an investment.

2. Possible scenarios for future oil prices and air quality degradation and the relationship of these scenarios to long term investment decisions

Peak world oil production and “the tipping point” for global environmental degradation will trigger a new era of rapidly increasing oil prices and environmental degradation initiating large social changes on a global scale. The emerging Chinese and Indian industrial economies will accelerate demand for an ever smaller energy resource resulting in higher oil prices. Also, their willingness to accept environmental degradation in trade for economic development will contribute to an accelerated deterioration of the environment with global consequences. Numerous sources point to the critical nature of these emergent realities. (Google “peak oil” or “tipping point”).

Cheap oil and the acceptance of the idea of a boundless natural world have come to an end. We are entering a new era where the old signposts have become unreliable. There is no accepted roadmap for our journey from this point into the future. Should we seek to moderate oil prices by exploiting heavy crude to the detriment of the environment? Or, should we regulate the use of carbon based fuels in an attempt to remediate the environment? Is there a framework for thinking strategically about the rapidly changing investment environment that we must confront? Is there a rational decision methodology for choosing among present investment alternatives knowing that big changes are in the future?

Assuming a continuation of the global market economy has consequences. As the price of oil rises, perhaps to levels that are multiples of current prices, and as environmental degradation begins to have a global impact on human health and mortality, economically viable alternatives to the way we currently live will emerge. The only “give” enabling an adaptation to this new reality and the continuation of the global market economy are large scale changes in the way we live, eat, and work. These changes will create investment opportunities but also introduce uncertainties and new sources of risk. Economic dynamics will force the social changes with new winners and losers.

Nothing in the real world increases at the same or higher rate without limit. Otherwise, we would not be here to speculate about the future. Countervailing forces will always emerge. In the case of oil prices, economic forces will force social changes which will cap the price. In order to simplify the presentation, we will concentrate on the scenarios illustrated by the first graph in Fig. 1.

NATURE's strategies. Long term investing in this new era can be thought of as a game we play against NATURE. NATURE's strategy will be future oil prices and environmental degradation. At the time of our investment decision we will not know which strategy NATURE has chosen. We must evaluate our investment alternatives in terms of assumptions we make about the unfolding over time of NATURE's possible strategies (Fig. 2).

If NATURE chooses the leftmost strategy then the pace of social change will be wrenching. The rightmost strategy would permit the pace of change to approximate the pace experienced in the first half of the 20th century. Although we might prefer that NATURE chooses the rightmost strategy (or fear the leftmost strategy), we cannot predict which strategy NATURE will confront us with because of the magnitude and global reach of the social changes rising oil prices will provoke. Increases in environmental degradation will show a similar pattern, perhaps with a different time scale.

For the purpose of illustration, we will concentrate on assumptions compatible with the continuation of the global market economy but allowing for the possibility of major social changes. Other sets of assumptions are possible. The point is that the decision maker will have to start with a set of assumptions because the future is unknowable. The assumptions we make to illustrate our decision methodology imply the emergence of new long term investment opportunities that are difficult to evaluate because of uncertainties and risk.

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