Investment Decisions as Choice under Uncertainty

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I. Introduction

In this paper firm investment and resource allocation behavior is analyzed as a two-stage decision process in an evolutionary context. The first stage is the allocation of finite and specialized decision-making capacities to searching for and responding to particular kinds of opportunities. This decision is modeled as choice under uncertainty using the Reliability Condition decision rule developed by Ronald A. Heiner. The second stage is the allocation of operational resources among the set of possible activities defined by the first stage. This decision is modeled as the maximization of expected value in the usual way.

The decision analysis offered here is based on the work of many others. The framework uses Heiner’s work directly.1 Langlois’ discussion of rationality and institutions has been of use, as has Nelson’s call for formal process models to represent economic activity.2

Section II of this paper contains the RC/Max decision analysis in its evolutionary context. In part A of section III the basic behavioral patterns generated by firms governed by this decision process are derived. In part B these predictions are applied to resource allocation and investment behavior. It should be emphasized that this discussion is a sketch of the possibilities of this approach rather than its complete development. Predictions for microeconomic resource allocation behavior can be derived based on the company’s present condition and past experience in relation to external conditions. Preliminary consideration of the behavior of a system of RC/Max governed firms indicates that the achievement of an orthodox competitive equilibrium is reduced to a very special case. At the macroeconomic level such a system could generate volatile investment behavior characterized by fast contractions of investment and slow recoveries under sufficient levels of uncertainty. And since much that is held fixed or taken as exogenously given within conventional optimization is allowed to change here, the analysis may have useful dynamic, evolutionary capacities that are not available within the static, equilibrium approach.

II. The RC/Max Decision Analysis in an Evolutionary Context

This analysis of firm behavior is based on a representation of the interaction between the firm and its environment through behavior over time. Through this process of interaction behavior is determined and the structure and capacities of the company evolve. At each time period the company’s internal conditions and its external conditions form the basis for the determination of behavior. This behavior will then have results that affect the firm’s internal conditions and perhaps also alter external conditions. Whether changed or constant, these internal and external operating conditions then form the context for the selection of behavior for the next time period.

A firm is seen as a layered network of rules and sets. A structural rule defines and organizes the control of the resources and capacities at the company’s disposal, and establishes a decision-maker or manager. A strategic rule defines the set of activities in which the firm can engage. And a selection rule will determine the set of activities in which it actually does engage at different points in time.

For the purposes of this analysis the capacities controlled and used by the company can be classified in terms of their use in either operational or decision-making activities. Operational capacities will be those used in the activities of interacting with the environment to achieve goals. These would include employee skills and time, financial resources, plant and equipment, raw materials, technology, and so forth. Decision-making capacities will be those used in making decisions about which activities to engage in, how to control, monitor, and administrate them, when to switch among activities, and when to engage in new activities. These capacities would include the accumulated information and expertise in interpreting it that are available to the decision-maker(s). Decision-making capacities are information and the management time and skills involved in gathering and processing that information in making decisions.

The structural, strategic, and selection rules of
this representation of a firm all serve as allocational mechanisms. The structural rule separates the capacities of the firm from the external environment and allocates control to some decision-maker (DM). The strategic rule defines a strategic set A of possible activities, allocating the decision-making capacities (DK) to searching for and responding to certain kinds of information and opportunities. And the selection rule defines a behavior set B of activities for actual operation: it allocates the operational capacities (OK) to specific activities at particular points in time and space. Therefore, given a firm with a certain structure and capacities, behavior is determined through a two-stage decision process: a strategic search decision and a selection decision. The average performance of the behavior selected from the strategic set must be measured and evaluated by the decision-maker. This conception of the internal characteristics of a firm can be incorporated into a simple depiction of interaction with external conditions.

At each time period information about internal and external operating conditions is gathered and processed by decision-makers. Decision-making capacities are allocated to the activities in strategic search set A, and operational capacities are allocated to specific versions of some or all of those activities in selection set B. This actual behavior interacts with external conditions with results affecting both internal and external conditions. Internally these results will be the level of average performance and any changes in decision-making or operational capacities that emerge from the experience of operation. These results then form the basis for next period’s decision-making. Note that within this simple representation all of the components can change, and that sources of changes in firm behavior may lie within the internal conditions of the firm as well as in changes in the external environmental conditions.

Within this evolutionary framework firm decision-making will be modeled as a two-stage process. The strategic rule which allocates decision-making capacities to a set of possible activities will be modeled using the analysis of choice under uncertainty developed by Heiner. At the second stage the actual activities of behavior set B will be selected by the maximization of the expected value of the potential activities in set A — this is the allocation of the operational capacities. Heiner’s Reliability Condition functions to direct the firm’s resources to activities that it can administer most reliably. The RC operates to reduce uncertainty at the level of the strategic search decision to calculable risk for the selection decision.

The treatment of the strategic search decision as choice under uncertainty is based on the characteristics of decision-making capacities assumed here. These capacities are information and expertise in interpreting that information. It is assumed that the process of making decisions using these capacities takes time. At any given point in time these capacities are finite. These decision-making capacities are also specialized: a firm will have more accumulated information and expertise concerning activities with which it has had experience. Since decision-making capacities are finite and specialized the firm’s decision-makers may face uncertainty in deciding about certain activities. Uncertainty means difficulty calculating the probabilities of various outcomes reliably, or even knowing what all the possible outcomes of some activity are. At the level of the strategic decision conditions can be so complex, unstable, and unfamiliar that they overwhelm finite and specialized decision-making capacities.

The Reliability Condition decision rule is being used here as a mechanism for the definition of the strategic set: the set of activities for which the company’s finite and specialized decision-making capacities are reliable enough to allow selection. If an activity does not meet the RC it is excluded from the strategic set A and it cannot be selected. Repeated application of the RC defines the strategic set A at some point in time.

The definition of the components of the Reliability Condition follows. This version of the RC involves considerable interpretation and application of Heiner’s framework, but the importance of his work for this analysis cannot be underestimated.

**A** : The strategic set of activities available for consideration by the firm. The firm may engage in these activities as operating conditions are appropriate. This set is determined and altered over time through the formation of a strategic rule using the Reliability Condition.

**X** : This will represent some activity that is being considered for inclusion in set A for some firm.

V(A) : This is the average performance of the entity’s strategic set over some period of time. Since the actual behavior is selected from that set, this
amounts to the average performance of behavior over several period's operations. How this is defined and measured can vary with the decision-makers of the firm in question and the survival criteria imposed on the firm by its external environment. However, in this context the percentage rate of return on resources invested can serve as a performance standard that reflects the operating conditions that face companies and also captures the way in which the decision to allocate finite and specialized decision-making capacities is a kind of portfolio decision.

**R**: The operating conditions that would result in an increase in average performance of the company's strategic set if the activity x were included in it. Under such conditions the performance of activity x would be higher than the overall average performance of the existing activities of the firm. R is the set of conditions such that V(x;R) - V(A;R) is greater than zero. (Note that the colon is used to mean 'given' here.)

**G**: The gain in average performance under those right conditions: G is equal to V(x;R) - V(A;R). There might be a range of G values associated with different 'right' conditions. The possible varieties of operating conditions and the average performance of the firm's current strategic set defines a set of potential G values and a set of R conditions. In the interpretation of the RC the important point will be whether G is high or low.

**W**: The operating conditions that would result in a decrease in average performance from activity x compared to that of the existing strategic set. W is the set of conditions for which V(A;W) - V(x;W) is greater than zero. The set of all possible conditions is therefore divided into right conditions and wrong conditions for some activity x, with this classification done relative to the performance of the company's existing activities. Of course, it may be difficult for management to make this distinction between right and wrong conditions with confidence, or even to be sure of the contents of the set of all possible conditions. Such a lack of reliability can be represented — see below.

**L**: The loss in average performance under the wrong conditions for activity x. L is equal to V(A;W) - V(x;W).

p(R): The probability of the right conditions for activity x occurring.

p(W): The probability of the wrong conditions for activity x occurring. Since the set of all possible conditions has effectively been divided into right conditions for x and wrong conditions for x, p(R) plus p(W) is equal to one.

**r**: p(x;R): The conditional probability that the firm decision-maker will actually select the activity x when the right conditions are present, so that a potential gain in average performance actually results. This conditional probability will be abbreviated as r for convenience sake. The higher an estimated r value, the less likely the decision-maker is to fail to choose x at the right time — to make a mistake of omission.

w : p(x;W): The conditional probability that the firm will actually select the activity x when the wrong conditions are present, resulting in a loss in average performance. This conditional probability is abbreviated as w. Note that p(x;R) plus p(x;W) do not equal one. Rather p(A;R) plus p(x;W) would equal one, where set A does not contain activity x. Similarly, p(A;W) plus p(x;W) would equal one. The higher the estimated w value, the more likely the decision-maker is to select activity x at the wrong time — to make a mistake of commission.

r/w : This ratio of the conditional probability of choosing x correctly to the conditional probability of choosing x at the wrong time will be called the reliability ratio. Its value can vary between zero and infinity. Its magnitude will be a reflection of the decision-maker's estimate of how reliable the firm's decision-making capacities are in identifying the right and wrong conditions for the activity x under consideration. The more complex, unstable, and/or unfamiliar those conditions are relative to the finite and specialized decision-making capacities of the firm, the lower the value of the reliability ratio will be.

These elements can be used in a criterion to determine whether to include the activity x in the strategic set A. It should be included, allowing possible selection, when such inclusion will result in higher average performance than excluding it. Since A is the existing strategic set without x, let A plus x be the same set with x added. The Reliability Condition developed by Heiner will indicate when the average performance including activity x will be greater than that without it: this means that V(A+x) is greater than V(A). The RC is derived by Heiner from an evaluation of when V(A+x) will be greater than V(A) using a Von Neuman-Morgenstern expected utility expression. The expression represents the decision-maker's attempt to evaluate the possible outcomes of allowing selection of activity x or not, considering the different possible outcomes of allowing selection of activity x or not, considering the different possible kinds of conditions, whether activity x would result in relative gains or losses under those different conditions, and how reliable decision-making might prove to be in identifying which
conditions will lead to a gain and which to a loss. The algebraic derivation of the RC presented by Heiner follows.\(^5\)

\[
V(A) = p(R) V(A; R) + (1-p(R)) V(A; W)
\]

\[
V(A+x) = p(R) r V(x; R) (1-r) V(A; R) + (1-p(R)) [w V(x; W) - (1-w) V(A; W)]
\]

where \(r = p(x; R), \; 1-r = p(x; W), \; w = p(x; W), \; 1-w = p(A; W), \) and \(1-p(R) = p(W)\).

Subtract \(V(A)\) from the expression for \(V(A+x)\) and simplify.

\[
p(R) r V(x; R) - p(R) r V(A; R) + (1-p(R)) w V(x; W) - (1-p(R)) w V(A; W) =
\]

\[
p(R) r (V(x; R) - V(A; R)) - (1-p(R)) w (V(A; W) - V(x; W)) = G(p) r - L(1-p(R)) w
\]

The final expression can be written because the definitions for gain and loss can be substituted in: \(G = V(x; R) - V(A; R)\) and \(L = V(A; W) - V(x; W)\). The conclusion is that \(V(A+x)\) will be greater than \(V(A)\) if and only if \(r w > (L - (1-p(R))) G(p)\). This is the Reliability Condition.

The strategic set \(A\) is formed through application of the RC to activities. If the left-hand side is greater than the right-hand side, the RC is met and the activity is reliable enough to be included in the set; if it is excluded. This expression is not unlike a reliable, relative expected value for including the activity. It contains relative gains and losses multiplied by their respective probabilities and weighted by behavioral reliabilities. When an activity meets this criterion, decision-making capacities are allocated to searching for and responding to opportunities to engage in that activity. But inclusion in set \(A\) does not mean that the activity is actually implemented in operation — that requires the next stage.

The application of the RC strategic decision rule defines the strategic set of activities in which the company may engage, and it governs changes in that set over time. For example, application of the RC might lead to a strategic rule that says the company can engage in activities \(x, y, \) and \(z\). If at some point activity \(w\) also meets the RC, the strategic rule changes, redifining set \(A\) to include activity \(w\).

Once the strategic set \(A\) is defined, the manager must select an activity or activities for actual implementation based on the nature of operating conditions. This is the second decision stage of the selection of activities for behavior set \(B\), which is modeled as the maximization of the expected value across the set \(A\). Activities with positive expected values under current operating conditions will be selected for implementation. This maximizing selection rule will be expressed as follows.

\[
EV_i: \text{The expected value of activity } i, \text{ one of the } n \text{ activities of the strategic set } A.
\]

\[
Q_{ij}: \text{One of the } n_j \text{ possible outcomes of activity } i \text{ under certain conditions.}
\]

\[
p(Q_j): \text{The probability of outcome } j \text{ for activity } i.
\]

\[
EV_i \text{ can therefore be expressed as } EV_i = \sum_{j=1}^{n_j} Q_{ij} p(Q_j). \text{ The maximization rule is to select behavior set } B, \text{ a subset of set } A, \text{ such that } \sum_i EV_i \text{ is a maximum.}
\]

This selection rule is to maximize the expected value of activities across the strategic set \(A\) of potential activities. All activities with positive expected values under conditions at a particular time will be selected while activities with negative expected values are eliminated. This maximizes the total return to the set \(B\).

One question that arises here concerns the possibility of resource or capacity constraints on the firm: if the firm has more positive expected value activities than it has operational resources and capacities to employ. To keep the framework simple I will assume that there is ultimately no constraint in terms of operational capacities. The firm can obtain operational resources for any expected value activity, but the cost of doing so will be added to the calculation. The true constraint in this model is not operational capacities which can be obtained as desired but decision-making capacities. The constraint is that the strategic decision must be made based on the decision-making capacities that the firm already has. While these capacities could also be increased and altered over time, the strategic decision is made with the information and expertise that the management already has at that time.

The two-stage RC/Max decision process presented above is an analysis of the strategic and selection rules and sets described as essential elements of an evolutionary representation of the firm. A firm has a structure that organizes the control of company capacities by a decision-maker(s). The decision-maker uses the RC governed strategic rule to define the set \(A\) of reliable and therefore permissible activities. This allocates the firm’s decision-making capacities to the evaluation of those reliable activities under existing operating conditions. This evaluation takes place at the selection stage as the set \(B\) of activities for operation is selected through the maximization of expected value across set \(A\).

This framework can be added to the depiction of the determination of firm behavior and the evolution of firm structure and capacities over time. As the firm operates the behavior set \(B\) of current
activities is adjusted and altered through a continuous monitoring process. Behavior can change as the company switches among the activities already in the strategic set A, following changing expected value calculations as internal and external operating conditions change. The behavior set can also change when the RC strategic evaluation allows new activities into A, therefore allowing their selection for behavior set B.

This RC/Max analysis depicts a sequence of things that must happen in order for the firm to actually allocate operational resources to some new activity x that would result in a change in behavior. First the decision-maker must receive or develop the idea of activity x or information about activity x, either from external or internal operating conditions. If there is no information about activity x the reliability ratio r/w is effectively zero, the RC is not met, and no RC evaluation is even triggered. If such information is received, an RC evaluation occurs. If activity x does not meet the RC no further search and response is done — no allocation of decision-making capacities will occur. Activity x is not in A and it will not be in B. If activity x is already in set A it now meets the RC criterion, decision-making capacities will be allocated to searching for and evaluating opportunities to engage in the activity. If the activity has a positive expected value it will then be selected for B; if it does not, it will not be in B, but it is still in A for possible selection at a later time.

Several aspects of this framework deserve mention at this point. One significant aspect is that the trigger for major changes in behavior — adding new activities to the strategic set A — can come from either internal or external conditions. The analysis is not limited to the examination of response to exogenous changes. It will also be able to represent changes in behavior that result from different levels of firm performance and from the processes of learning and creativity that develop through operation over time. Changes in decision-making capacities and changes in performance will affect V(A) and r/w values, potentially altering the strategic set.

It is also important to note that the activities evaluated and selected in this analysis can be any kind of operation in which a firm engages. The basic activities of production and distribution are involved, but any other activity — research, training, management, advertising, etc. could also be considered. In addition, activities that involve changing the structure and capacity of the firm itself will be chosen through the same decision process. Activity x could be investment in more or different productive capacity. It could be investment in more decision-making capacity. It could be a change in the organization of the firm, or even a change in the decision-maker controlling the firm. Such activities that involve altering the structure and capacities of the company will be particularly subject to uncertainty since they depend upon expectations about future conditions. This analysis of firm decision-making therefore provides a unified view of the determination of firm behavior. Switching between routine operational activities is placed in the same context as major creative strategic changes in behavior, structure, and capacities.

A final comment concerns the assumptions about risk and uncertainty embodied in the conceptual framework of the analysis. The decision rules are meant as abstract representations of important aspects of firm decision processes rather than a literal account. At the selection stage the managers are evaluating a restricted set of possible activities that have passed the Reliability Condition and for which they must have sufficiently reliable decision-making capacities for that to have happened. Since they have relevant information and expertise, it seems reasonable to assume that managers are capable of calculating risks and probabilities across this limited set of actions and outcomes. If objective probability distributions are not known, subjective probability estimates could be based on experience. The whole point of the strategic set is that it contains the activities about which the managers can be most rational — so that they can decide under conditions of risk rather than uncertainty.

However, at the prior strategic stage the whole point is to make decisions about adding new activities for which complete information and expertise may not be available. Yet the RC components are in some cases defined as probabilities. These components are intended to represent the kinds of considerations that the decision-maker must take into account. If relevant expertise and information are lacking, he or she must estimate or guess the values of the RC components. All that is assumed is that the decision-maker is able to assign high, low, or
medium values to these components — this is enough to generate the patterns of RC-governed behavior. All that is necessary is for the decision-maker to be able to say “I know nothing about this kind of activity — reliability ratio low,” or “this activity is similar to things that I already do — reliability ratio high,” or “this activity seems to have higher average performance than my existing operations — relative gain high,” and so forth. This is not intended as a precise quantitative analysis. Patterns of behavior will emerge from the assignment of large or small values. The nature of these behavior patterns will be discussed in the following section.

III. RC/Max Behavioral Predictions
A. Basic Static and Dynamic Propositions

In the context of this analysis a company is seen as interacting with its external conditions through operations over time. The managers are continually monitoring internal and external operating conditions, changing behavior set B by switching among the activities of strategic set A, and sometimes also changing that strategic set. When will such changes in strategic set A mean that a firm engages in new activities? When will the firm engage in activities that involve changing its own capacities and structure? The RC/Max decision analysis can be used to predict when such changes are likely to occur by predicting the expansion and contraction of the strategic set under different internal and external conditions.

In this analysis the behavior of a company is jointly determined by the two-stage decision process. To be put into operation activity x must meet both the RC and the Max criteria: strategic set A will contain all activities for which the r/w is greater than 1-(p(R))/Gp(R) and selection set B will contain all those activities of A that have positive expected values. Since in this framework the RC strategic rule functions as a kind of gateway that controls the addition of new activities, it is the RC predictions about allocating DK to that new activity and allowing response to information about it that must be examined. By determining what to even consider doing the RC dominates the overall content of what is done, although operations at any particular point in time are determined by the maximizing selection of activities.

In this discussion of the basic behavioral patterns of RC/Max-governed firms I will first discuss the static predictions in terms of the likelihood of exclusion of some activity x from strategic set A. Then I will discuss the different possible patterns of response to change shown by such firms.

Static Proposition

Some activity x is most likely to be excluded from some firm’s strategic set A when some, all, or some combination of the following conditions holds:

1. The activity and the conditions related to it are complex, unstable, and/or unfamiliar to the firm’s decision-making capacities. Any one of these can mean little useful information and expertise and therefore a low reliability ratio value.

2. The firm’s existing average performance is high relative to the potential range of results from the activity. This tends to increase L and decrease G, and it also can decrease the possible conditions that can be classified as “right” for activity x, therefore also leading to a low probability of right conditions. So G and p(R) are low and L and 1-p(R) are high.

3. The right conditions for the activity, as defined by relative comparison of potential performance, is seen as unlikely given prevailing external conditions. Given definitions of G and R, p(R) is low due to the perceived probability structure of the external environment.

This proposition emerges from the definitions and the simple mathematics of the Reliability Condition. Note that the inclusion of some activity x would be predicted under the opposite of the conditions and component values cited above. Simple, stable, and familiar conditions and low average performance would favor inclusion due to high r/w, high G, low L, and high p(R). Note also that the result of inclusion or exclusion will depend on the interplay of the different elements within the RC. Recall that all that is assumed here is the ability of the decision-maker to assign high, medium or low values to these components based on existing decision-making capacities. To the extent that they feel unable to do this reliably the reliability ratio drops and the activity will probably be excluded regardless of the estimated values of the other components. In this way an extreme value for one of the RC components could overwhelm medium values of the others. In some cases offsetting values of the elements could counteract each other within the criterion, leading to indeterminate implications. The clearest predictions would emerge when all the components tended toward either inclusion or exclusion: for instance low r/w, low G, and low p(R). This framework will be able to indicate when certain changes in behavior are most likely given the present and past experience of the decision-makers and the nature of external conditions.

Although in many cases it is the combinations
of the RC element values that will generate the predictions of inclusion or exclusion, the reliability ratio still acts as the primary force. A reliability ratio of zero — complete absence of information about activity x and/or expertise with which to interpret it — essentially cuts off the RC evaluation. Conversely, a value of infinity for the r/w renders the other component values irrelevant: the activity in question would automatically be included in the strategic set regardless of the values on the right-hand side of the inequality, allowing selection of the activity in response to perceived positive expected value opportunities. It would also be possible to assume a reliability ratio of infinity for all possible activities and conditions. In this case there is no restriction on the strategic set A; any positive expected value activity can be selected. Such an assumption reverses the assumption that conditions can be uncertain enough so that a decision-maker may not have the necessary decision-making capacities, especially at first. Decision-making capacities would not be scarce relative to the decision task, there would be no need to allocate them, and firm behavior would be determined through the maximizing selection of expected value activities alone.

The static proposition can be used to analyze response to changing conditions over time: when will the RC/Max governed firm respond to the changing opportunities presented by evolving operating conditions. The question will be framed in terms of when an immediate, lagged, or lack of response is most likely to occur. Suppose that a firm receives information that indicates the possibility of profit opportunities in activity x. This information could be gathered from the external environment or it could stem from ideas developed internally. For the sake of this exercise, also suppose that positive expected value opportunities in activity x do in fact objectively exist for the firm. This means that if x meets the RC so that x is in A it will be selected by the maximization rule. The question is whether and when the firm will be most likely to allow response to information and selection of x: under what conditions will activity x pass the RC?

**Dynamic Proposition**

1. There will be an immediate response to information about activity x when x is either already in strategic set A or it meets the RC when evaluation is triggered due to receipt of information about the positive expected value opportunity. This will be most likely to be true if some or all of the following conditions hold. If operating conditions related to x are simple, stable, and familiar relative to the manager’s decision-making capacities, or if those capacities are substantial enough to allow for reliable behavior despite complexity, instability, and unfamiliarity. This would mean a high r/w. If average performance is low it will also increase the likelihood of immediate selection due to higher G, lower L, and higher p(R).

2. There will be a lagged response to information about activity x if initially x does not meet the RC, but with the passage of time changes occur that allow it to meet the RC and to be selected for set B. Initially the reliability ratio is too low and/or the average performance is too high. Over time perhaps conditions stabilize and become more familiar, more information accumulates, or average performance of existing activities drops. The r/w rises and V(A) falls enough to let x into A.

3. There will be a lack of response to opportunities in activity x when even with the passage of time the changes in the RC values necessary to allow x into A do not occur. The conditions could continue to change so that the opportunities turn out to be temporary. Or even if the conditions favorable for x persist, the overall environment is too complex, unstable and unfamiliar for the reliability ratio to rise. Or since the firm does not engage in activity x it accumulates no relevant specialized expertise and information, so the r/w stays low. Or there might be no decline in average performance to force the activity over the barrier of unfamiliarity into the strategic set.

This analysis of the response to change indicates that such response can only be ensured if the nature of the change is restricted in a special way or if perfectly reliable decision-making capacities are assumed. The latter assumption means that conditions cannot be so challenging that specialized expertise is required. The restriction on the nature of change would be that after an initial change conditions always stabilize so that managers become more confident of their ability to interpret them reliably after the passage of time. A scenario of equilibrium, a single change, and adjustment to new equilibrium is the basic comparative statics approach to change. But the behavior of RC/Max governed firms can still be analyzed even if conditions continue to change and if more than one change occurs at a time.

This dynamic proposition therefore indicates that if operating conditions are complex, historically unique, and evolving, and if decision-makers do not have infinite and perfect decision-making capacities, patterns of lagged and lack of response to change will be observed in RC/Max companies.
This behavior will have significance for the behavior of an economy made up of such firms, to be discussed below.

It must be noted that the framing of the dynamic proposition is artificial in that it is assumed that a positive expected value opportunity for the activity x actually exists objectively. This means that when the RC blocks the search for and selection of activity x a real opportunity is being missed. If that assumption is relaxed, then when a company does not select x it could be either because it does not meet the RC or because there are in fact no perceived positive expected value opportunities. The point is that with the RC/Max decision process a lack of response to information or not engaging in an activity does not necessarily mean that there is no profit opportunity. In this framework real opportunities can be temporarily or permanently missed due to conditions of uncertainty. The presence or absence of sufficient and specialized DK can dominate patterns of behavior by restricting response.

B. Resource Allocation and Investment Behavior

In order to explore the possibilities of this decision model I will apply it to investment decisions by firms. Investment is defined here in its broadest sense as resource allocation overall as well as additions to productive capacities. The basic task of the firm is to define an area of reliable behavior where it can engage in the rational maximizing selection of activities. Firm managers make an RC-governed strategic decision under uncertainty to determine this set of reliable activities. This strategic decision allocates the specialized and finite decision-making capacities of the firm. The selection decision then allocates the operational capacities of the firm, including the productive resources and financial resources. Investment behavior and the allocation of operational resources which it embodies are therefore the result of two allocations: the allocation of DK determines the possibilities for OK.

Many company resource allocation decisions will be routine maximization of expected value selections of familiar or ongoing activities that are already in the strategic set A. The RC/Max decision rules will tend to allow unrestricted response to changing opportunities for such routine activities, unless particularly unfamiliar, complex, and/or unstable conditions lead to high uncertainty and low reliability ratios even for such familiar actions. But the RC/Max analysis will be particularly useful for the activities that in themselves involve inherently high levels of uncertainty. Such activities will include those that involve future conditions, that are complex, and/or that are unfamiliar. Investment in new operations and new productive capacities is this kind of inherently creative and uncertain activity. In this section I will briefly sketch the behavioral implications of the RC/Max analysis for investment behavior at the microeconomic, market, and macroeconomic levels.

**Microeconomic Analysis**

At the microeconomic level this approach can generate predictions concerning major strategic changes in investment behavior: changes in activities that involve changes in the allocation of decision-making capacities and then also in the allocation of operational capacities. These basic patterns of strategic behavior arise from the propositions discussed above.

Firms will be most likely to continue doing what they are already doing. They will be very slow to leave familiar activities. Firms tend to diversify into unfamiliar activities or to invest in innovative activities either when forced to out of weakness or when developing strength makes such change possible. A firm will do something new — add some new x to A — either when average performance drops, increasing the potential gain far enough to overcome the low reliability ratio, or when the accumulation of information and expertise with experience raises the reliability ratio even for unfamiliar activities. Necessity can be the source of innovation, but so can experience and creativity.

These basic patterns of strategic investment behavior are generally consistent with empirical studies in these various areas. It should be noted that I do not claim that such patterns cannot be explained within a purely optimizing decision model, without the satisficing RC context. This behavior could be modeled as optimizing selection subject to costs of information or information-processing, or the strategic decision could be modeled as a prior optimizing search decision. But any optimization explanation would depend upon the assumption of an appropriate cost structure — of information or of search — to generate the pattern of resource allocation. In the RC/Max framework the explanatory power comes primarily from the presence or absence of specialized decision-making capacities, and the production of such capacities through operation over time can also be explained. The production of the framework of means and ends for the optimizing selection can be represented. The
patterns of behavior emerge from the historical experience and current situation of the firm in relation to external conditions, not from some assumed cost structure.

This framework can therefore be contrasted to the orthodox optimization approach in that the forces that channel the allocation of resources are endogenous to the model rather than assumed as exogenously given. The RC/Max framework also has the capacity to represent internal sources of change in behavior like the creation of new activities as expertise grows with operation over time. This means that perhaps innovation and technological change could be analyzed within the model rather than treated as exogenous. Still another point is that since the RC/Max includes a representation of the firm as a system of rules, and since the activities selected can include activities of changing those rules, the framework has the capacity to analyze the process of structural evolution over time. It might serve to provide a formal analytical framework for the kind of evolution through the interaction of structure and strategic behavior depicted by Alfred Chandler in his studies of business history.

The RC/Max could be incorporated into a view of the company as a mixed feedback system evolving over time. There would be both negative and positive feedback mechanisms, so that the system contains forces for continuity and forces for change. A negative feedback mechanism within the RC/Max can result from a decline in average performance. Such a decline will tend to trigger changes in behavior as other activities appear more attractive. However, when there is an increase in average performance, the effect is like a positive feedback mechanism. An increase in V[A] concentrates operations on those successful current activities — any others look less attractive. Higher performance also means that more resources are controlled by the firm and specialized decision-making capacities are accumulated through this successful operation. More resources make the expansion of existing operations easier. A greater size may lead to the ability to influence external conditions, which could lower uncertainty, raising the r/w for many activities, and perhaps leading to changes in behavior. The accumulation of expertise and information will also lead to higher reliability ratios, facilitating expansion and innovation. Note that in this system both a decrease and an increase in average performance can actually lead to changes in firm behavior: changes out of necessity and changes out of strength.

**Market Competition and General Equilibrium**

The achievement of an orthodox competitive equilibrium depends upon a process of competition among firms. But if the system is made up of RC/Max firms, this process of competition may not be sufficient to ensure this result. Winter has defined a competitive equilibrium among profit-maximizing firms as having two basic characteristics. One is that all firms are earning the normal rate of return, so that there are no excess profits or losses to provide an incentive for entry or exit. The other is that all potentially profitable techniques or opportunities have been tried — there are no missed profit opportunities. For the process of competition among companies to generate these conditions entry must always occur in response to excess profits and all possible activities must be tried by some firms.

But in a system of RC/Max firms such trial and entry in response to positive expected value opportunities may not be forthcoming. Such a competitive response can only be ensured under restrictive assumptions about the level of uncertainty confronting participants. Either decision-makers must have infinite relevant specialized expertise and perfect information or simple, stable, and familiar conditions must prevail. The reliability ratios for activities in response to profit opportunities must always be high enough for some firm so that the firm will engage in the activity. If the RC/Max companies operate in an environment of historically evolving conditions, and if it takes time to learn about complex conditions, the orthodox competitive equilibrium appears to be reduced to a very special case.

In addition to undermining the achievement of the orthodox competitive equilibrium in a particular market, this approach will have implications for the general equilibrium case. These implications could emerge even when only some of the participating firms have RC restrictions on their responses to change. If even some of the firms respond to changes with a lag or fail to respond at all the equilibrium position of the system is affected. In a completely different theoretical context Akerlof and Yellen have shown that the presence of some non-maximizers along with maximizers in a system will have first-order implications for the equilibrium. The result with all max and the result with some max and some non-max may be quite different. At a point in time the system might contain firms with very high decision-making capacities that will achieve high performance and survive. It might also contain firms with relatively low DK due to inexperience — they are still
learning about operating conditions — or firms with poor managements that are destined to fail eventually. The presence of a variety of capacities will lead to a variety of reliability ratios for particular activities in response to change. Lags or lack of response by some will alter the general equilibrium.

However the equilibrium analysis of RC/Max firms might work out, the real payoff of this approach may lie in the possibility of developing an alternative way of analyzing change. Orthodox comparative statics involves equilibrium, a single exogenous change, and the new equilibrium, with the rest of the system held fixed. The RC/Max decision analysis is placed in the context of the process of operation and evolution over time. This framework has the potential for analyzing change in a number of ways that are precluded from the static orthodox optimization model. The processes of learning and adjustment to change can be represented, rather than just the end result. Continuous change and multiple sources of change can be admitted, and behavior can still be analyzed. Endogenous sources of change in behavior can also be represented: creativity and the development of new ideas and activities. The framework can represent changes in behavior that involve changes in capacities and/or changes in structure because of the historical and evolutionary approach. The presence of positive feedback mechanisms within this representation of the firm seems likely to make behavior path dependent over time — or characterized by "sensitive dependence on initial conditions" in the terminology of the mathematics of chaos and complexity. Clearly and mathematical representation of this evolutionary process system would involve differential equations and nonlinear dynamics rather than the simple calculus of comparative statics.

**Macroeconomic Investment Behavior**

At the macroeconomic level investment theory concerns fluctuations in the aggregate level of investment spending. The goal is to identify those variables whose changes will affect most firms’ investment decisions in the same direction at the same time. Investment models based on the cost of capital and the level of change in output have been less than fully satisfying intellectually and in empirical testing. In part these problems may stem from difficulty in modeling the large expectational component in the investment decision. The importance of expectations is based on the very nature of the creative act of investment in new productive capacities for use under unknowable future conditions.

The RC/Max analysis can be used to address behavioral response to changes that involve uncertain future conditions. The level of uncertainty will operate through the RC strategic rule to expand and contract the strategic set A, generating changes in investment behavior that may not be directly attributable to changes in a particular exogenous variable. Since the RC restrictions are most distinctive in their prevention of selection, the analysis can be used to tell the stories of a sudden drop in investment and a lagged response to favorable changes.

A sudden drop in the level of investment spending can emerge from a novel and unexpected change in operating conditions. This can result in unstable, unfamiliar, and/or complex conditions. The level of uncertainty for all decision-makers increases at once, the reliability ratios for many activities will decrease, and the strategic sets will contract. Selection of some investment projects will be prevented even if the positive expected value of the activity is not directly affected by the particular change in operating conditions. It is as if managers no longer trust the reliability of their own estimations. As many investment projects are cancelled, the aggregate level of investment spending drops. As time passes, the implications of the initial change in conditions may become more clear. Conditions stabilize and become more familiar, and there is time to gather and process information. The overall level of uncertainty falls, reliability ratios rise, and strategic sets expand to again allow selection of more investment activities. But the drop in investment spending may already have created a recession.

Another RC/Max story is that of a lagged response to some change in operating conditions. Suppose that some condition changes in a way that is favorable to investment projects — for instance, a decline in the interest rate, a tax cut, an increase in consumer confidence or consumer spending, etc. Such a change would tend to increase the number of investment activities with positive expected values for selection. However, the level of uncertainty happens to be high — if conditions are complex, unstable, and unfamiliar relative to decision-makers’ expertise — generally low reliability ratios will cause contracted strategic sets. Managers will not select even investment projects that look promising under existing conditions due to the high uncertainty. If conditions stabilize over time and more information is available, reliability ratios would rise, and the level of investment spending would respond to the original favorable change in conditions (if it is still in effect).
It is as if varying levels of operational uncertainty can break the direct connection between a change in an exogenous variable and the effects on investment behavior through positive expected value calculations. Uncertainty introduces static or background noise that intermittently obscures causal behavioral relationships. (Heiner's original derivation of the RC involved signal detection experiments with background noise.) The effects of changes in variables vary with changes in internal capacities and external conditions. Sometimes firms would be responding to change with unrestricted maximizing behavior. At other times they would exhibit lagged, adaptive responses. Or there might be a combination of firms with various levels of decision-making capacities and different response patterns. The RC/Max analysis could represent such different situations and provide an explanation for the different patterns of response under different conditions. The brief sketches above appear to indicate that the presence of uncertainty can result in an asymmetry in the response of investment behavior to changes in operating conditions. Under uncertainty, investment can drop quickly and be slow to recover.

The general RC/Max approach might also prove useful in modeling any kind of behavior that involves the formation of expectations, not just investment behavior: for example investor behavior in financial markets and the price expectations of workers. This analysis might provide an integrated framework for the analysis of the role of expectations — how they are produced and how they change. It might offer a way to synthesize rational and adaptive expectations. The Reliability Condition could be seen as a way of determining when and where an agent considers himself to have "rational expectations". The model of the economy on which those expectations are based might change only adaptively as the structure of the actual system evolves. Under low levels of uncertainty agents might behave as if they have rational expectations. At high levels their behavior might appear to be based on adaptive expectations as the RC temporarily restricts response to change.

IV. Conclusion

The RC/Max decision analysis predicts microeconomic resource allocation behavior based on a company’s present condition and past experience in relation to the nature of existing conditions. Preliminary consideration of the behavior of a system of RC/Max firms indicates that the achievement of an orthodox competitive equilibrium is reduced to a special case under restrictive assumptions. At the macroeconomic level such a system could generate volatile investment behavior characterized by fast contractions of investment and slow recoveries under sufficient levels of uncertainty.

These behavioral predictions concern likely patterns of behavior — it may not be possible to generate unique and determinate predictions for particular cases. But this lack of precision is offset by the expanded explanatory capacity of the RC/Max analysis over a maximizing decision rule alone. This framework can analyze changes in ways that maximization alone cannot. The RC/Max can represent the process of learning through experience and the process of adjustment to change. It can allow multiple, simultaneous sources of change and continuous change rather than requiring "ceteris paribus". It can also allow components like technology, organization, and capacities to change endogenously rather than assuming such variables to be fixed and exogenously given. It could represent endogenous sources of change that emerge from learning and the development of innovative ideas rather than treating such dynamic processes as determined outside of economic analysis. Yet the framework still contains the traditional maximizing decision rule: under low uncertainty reliability ratios are so high that the firm is back in the orthodox context of maximization alone.

The RC/Max analysis is intended as a contribution to the development of an evolutionary approach to the analysis of economic behavior. Since it is a synthesis of a non-maximizing or satisficing rule and a maximizing rule the useful aspects of each approach can be employed. But in this synthesis the Reliability Condition dominates maximization, determining the context and the constraints that frame maximizing behavior. Therefore although the framework incorporates the orthodox approach the positive and normative behavioral implications may turn out to be quite different.

Notes:
2. Richard R. Nelson, "The Tension between Process Stories and Equilibrium Models: Analysing the Productivity...
Growth Slowdown of the 1970s," in *Economics as a Process* edited by Langlois; and Richard N. Langlois, "Rationality, Institutions, and Explanation," from the same.


4. These definitions are based on Heiner's definitions in his development of the Reliability Condition. They are interpreted in application to this case. See Heiner, "Uncertainty, Signal Detection Experiments, and Modeling Behavior," 69-75.

5. Ibid. 99-100.


