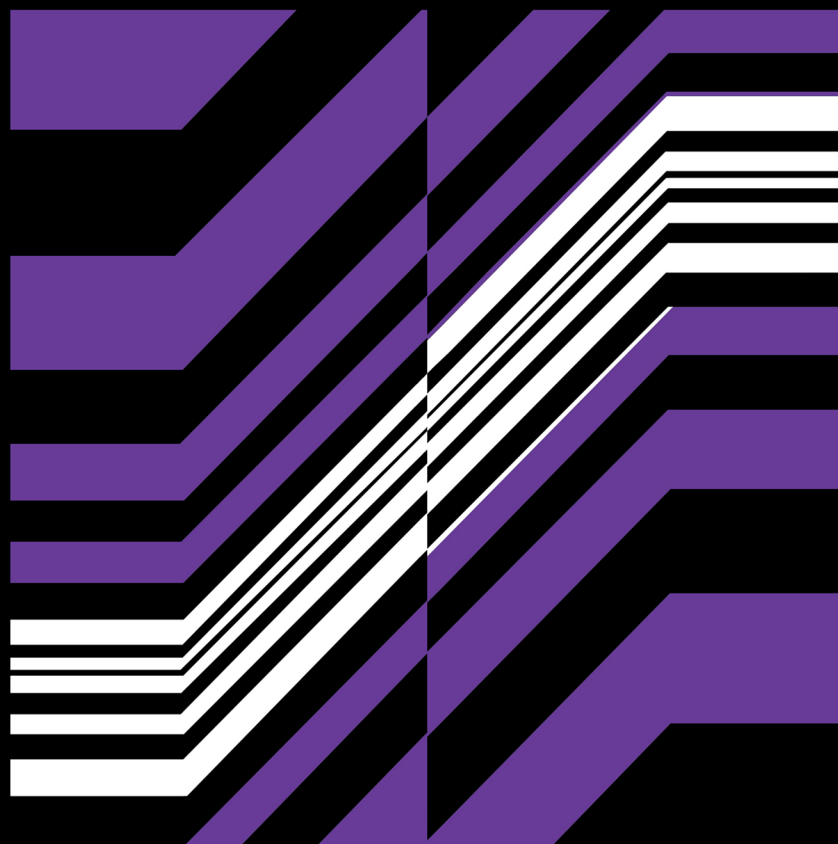


A Political Theory Primer

Peter C. Ordeshook



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Peter C. Ordeshook

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Introduction

V.O. Key, in his introduction to elementary statistics, wrote: "Most political scientists, accustomed as we are to other modes of analysis, bristle at the sight of even the most common statistical symbol."¹ This reaction no longer characterizes our discipline since nearly all serious researchers appreciate or have grown accustomed to the principles of hypothesis testing, regression analysis, simultaneous equations estimation, and multivariate scaling, and the terminology and notation of R-squares, F tests, Durban-Watson statistics, and maximum likelihood estimators are commonplace in our journals. However, Key's characterization rings true if we substitute the words "the notation and concepts of formal political theory" for "statistical symbol," because few political scientists are comfortable with ideas such as Nash equilibrium, extensive form, stationary strategy, separable utility, multidimensional issue space, or repeated game.

This fact is unfortunate, because these concepts and their attendant mathematical notation, properly used, augment our reasoning with tools that allow us to detect inconsistencies and ambiguities in our thinking. Unfortunately, the language of mathematics and, thus, the language of political theory, is too often inaccessible to those who have entered the discipline not to understand mathematics but instead to understand and perhaps influence politics. However, those who are interested in understanding the inner logic of politics cannot forever ignore the opportunities for augmenting their thinking with formal constructs. Such constructs constitute too powerful an instrument of logical reasoning, and politics is too important a subject to leave its study to the often imprecise and logically flawed world of intuition, "wisdom," and verbal analysis—to a domain in

¹V. O. Key, *A Primer in Statistics for Political Scientists*, New York: Crowell Co., 1954.

which the well turned word or eloquent phrase, however imprecise or illogical, carries the argument and dictates policy.

Of course, mathematical notation alone cannot supply us with understanding any more than entering random numbers into some well-constructed computer can produce something other than nonsense as output. In order to put mathematics meaningfully to work we must operate within an explicitly defined paradigm—a view of the world that guides both our intuitive reasoning and our use of mathematical ideas. In short, we must find a way to use notation and formal argument in an efficient way—in a way that ensures learning something about politics and not merely something that might be taught more effectively in a mathematics department.

This volume offers an introduction to one view of the world—the **paradigm of rational choice**—and to the part of that paradigm, game theory, that is of special significance to politics. Thus, this volume seeks to communicate the logical structure of a set of ideas that allow us to think about and to model a diverse range of political phenomena by using a single set of principles about individual decision making when those decisions are made in the context of institutions that we choose to call political.

Because this is an introductory text, we will not dwell on formal niceties. Indeed, we want to avoid the error made by too many practitioners in the field who become overly enamored of notation and who judge their colleagues' contributions by the skill with which that notation is manipulated rather than by substantive import. Thus, rather than survey the literature on political theory, we will focus instead on those ideas that point the way to key theoretical insights about some specific political processes. In particular, we provide an introduction that examines answers to such questions as:

1. How should the two major parties in a plurality-rule election system respond to the threat of entry by a third-party candidate?
2. Why do the plurality rule procedures of U.S. elections yield, in general, competition between only two major parties?
3. Are low levels of turnout necessarily symptomatic of something amiss in a democracy?
4. Should parties always prefer to control as many seats as possible in a legislature?
5. Does a poorly informed electorate create an inherent policy bias favoring those who can afford to secure good information about government policy?

6. Can social outcomes appear irrational even though everyone in the society satisfies nearly anyone's definition of rational?
7. Why is it that Congress often devotes more time and effort to debating procedures than it does to debating the actual legislation under consideration?
8. Are the votes legislators cast always good indicators of their assessments of their constituent's preferences, even among legislators whose primary goal is to win reelection?
9. What kinds of legislation are likely to induce legislators to trade votes across issues—to vote-trade (logroll)?
10. Does the committee system of Congress lead to outcomes that differ in a consistent way from the outcomes that would prevail if the Congress as a whole debated each and every measure?
11. Why is tax reform such an especially problematical form of legislation to consider, especially in an election year?
12. Why are congressional incumbents so frequently reelected despite the fact that Congress as an institution is held in low esteem by the public?
13. Should we attribute conflicts between a president and members of Congress merely to a clash of personalities, or are there explanations that derive from the fact that presidents and members of Congress are elected in different ways?
14. Aside from their general distrust of voters, what theoretical rationale is there for the indirect democracy bequeathed us by the Framers of the U.S. Constitution—in particular, for a bicameral legislature?
15. Why does the government regulate the rates charged by taxicab drivers and interstate moving companies, while at the same time it fails to regulate the prices of automobiles and most other major consumer purchases?
16. It is often asserted that “special-interest groups” buy politicians and control politics, but what of the view that campaign contributions correspond to politicians expropriating from interest groups?
17. When is it advantageous to commit to a decision before others and when is it more advantageous to hold off making commitments?

18. What are the conditions under which international systems will be stable, and how has the contemporary technology of nuclear weapons affected these conditions?
19. When everyone knows that everyone else is capable of deception, is it ever the case that a strategy of deception is more likely to succeed in achieving specific aims in international politics than a strategy of truthfulness?
20. What is the underlying structure of nuclear deterrence, what are the conditions under which such deterrence can be expected to work, and when can it be expected to fail?
21. Are the seeds of arms races and international conflict sown in human nature?
22. What role does verifiability play in strategic arms-limitation talks, and what degrees of verifiability are sufficient to ensure a "workable" arms-reduction treaty?

However, before proceeding, we would like to offer several special notes of caution. First, it will become apparent that modeling political processes frequently requires the imposition of a great many assumptions in order to render an analysis analytically tractable and intuitively understandable. We raise this issue here to confront directly the mistaken belief that, owing to such assumptions, formal theory is more limited than "informal" theory. It is certainly true that by making assumptions explicit, we reveal the limitations of our analysis. However, it is hardly the case that an analysis is more general if its assumptions are obscure, and we should discount the weight given to an argument to the extent that it cannot be shown to follow logically from a set of explicit assumptions about well defined primitive variables. Those who dismiss an idea, moreover, because its initial form imposes severe assumptions should be cautioned about failing to understand the processes whereby theory is developed. If, after establishing an initial representation of a situation, we deem that representation promising—either because it offers an unanticipated insight or because we did not appreciate beforehand the opportunity to model the situation in precisely the way shown—we can begin to weaken or generalize the initial assumptions. Hopefully, a general pattern in the analysis will emerge so that eventually a wholly general result can be established as a "first principle."

Related to this argument is a second note of caution, which is that it is incorrect to believe that the process of generalizing results will

eventually lead to “complete” models of political processes. Indeed, only the naive student believes that we can understand most of politics merely with a sustained effort at formal modeling and game-theoretic analysis. Such a goal remains out of reach even in the natural sciences, which is why we distinguish between science—the discovery of first principles—and engineering—the application of those principles, in combination with experiment, experience, and common sense, to specific “real world” problems. In a primitive sense (primitive, because our theory is far from complete), the material covered in this volume concerns first principles, and the models we offer (as well as those offered in the literature) should not be interpreted as wholly satisfactory descriptions of any specific ongoing political process or institution. Instead, they are merely a piece of the puzzle, and the insights that contemporary political theory offers must be combined in an artful way with a substantive understanding of the problem at hand gained through experience. Unfortunately, we cannot communicate either art or experience here, and thus, the approach we introduce cannot preclude the necessity for learning about politics in other ways.

Another reason for not assuming that formal modeling can solve all of our problems is that a great many first principles remain to be discovered. For example, we are only beginning to understand how to model cooperative action (coalitions and the enforcement of agreements) and how to incorporate the incomplete information that pervades most decision-making situations into our game-theoretic models. Similarly, we often hear it said that the “rational choice” view of the world is flawed because it is self-evident that people are not rational—that their actions are often random or self-defeating, or, worse still, that the limited capacity of the brain itself and of people’s abilities to make sense out of their environment limits their ability to function in accordance with the mathematical precision of formal theory. All of this may be true, but it ignores the fact that we cannot yet offer an unambiguous definition of rationality and that we can interpret the fundamentals of theoretical inquiry as being concerned precisely with this definition. Thus, although clever verbal argument coupled with a crude familiarity with bits and pieces of theory may win a coffee-table debate on the paradigm’s pros and cons, such a debate is what we want to avoid in favor of a clear understanding of issues already well articulated in the literature.

One of our goals, then, will be to reveal some of the ambiguities that characterize research. Understanding these ambiguities will give us some insight into what we might expect from those who work at

the forefront of theoretical developments, and it will also tell us what to demand of them so that their efforts will provide us with a better understanding of reality. This appreciation opens our eyes to topics that we imperfectly understand but which fuzzy or informal thinking has heretofore obscured from view.

1

Representation of Political Processes

1.1 The Basic Perspective

We begin with the assertion that all of politics concerns the actions of people whose fates are interdependent, where the nature of that interdependency is determined in significant part by institutions we choose to call political.

Such a characterization of politics may appear obvious or redundant, but it has profound consequences for the way we think about our subject. It implies that explanations of events focusing on the actions of a single individual, although perhaps contributing to our understanding, cannot provide a scientifically valid, causal explanation for those events. Arguing that the absence of a key legislator from a vote “caused” some bill to pass or fail ignores the fact that this absence is decisive only if the votes of others, as registered through specific institutional procedures, render that legislator’s vote pivotal. Attributing electoral defeat to a candidate’s stand on some issue ignores the fact that the defeat requires preferences among voters of a particular sort, it requires that voters be cognizant of the candidate’s position, it requires that the candidate’s opponent not be associated with an equally untenable position, and it presumes the existence of electoral procedures that allow more profitable campaign tactics. Judging an event such as the assassination of a national leader as the cause of a war commits the error of failing to see that an assassination, although perhaps a necessary condition for the outbreak of conflict, cannot be a sufficient condition: leaders must still decide between war and peace in light of their ultimate objectives, taking account of the responses of others to their actions, both in the international arena and domestically. The event may reveal new information about an adversary or an ally, or it may change military capabilities and make conflict more or less attractive for

one side or another, but we cannot attribute cause until we understand the interdependent context of events.

These examples of things political reveal that our study must take account of three things: (1) the responses of decision makers to the fact of interdependent choice, (2) the role of institutions in determining the nature of that interdependence, and (3) the goals of individual decision makers as they are expressed through action in the context of specific institutions.

1. Notice that it is not sufficient that we as analysts understand that political outcomes are dictated generally by the actions of two or more decision makers. We must also accommodate the possibility that political decision makers themselves understand and react to this fact. And once we make this accommodation, seemingly intuitive expectations about outcomes are readily questioned. Consider, for example, a scenario in which a star quarterback is injured and is replaced with someone who is known to be far less proficient at passing. In this instance we might predict that the offense will pass less frequently. However, notice that it also seems reasonable to suppose that the defense is aware of this situation, and that it can anticipate fewer passing plays and more running plays, in which case it will devote more attention to a running defense. But now we have a new problem: if the offense anticipates this response on the part of the defense, then it might reasonably choose to pass more frequently with its inferior quarterback. But then again, if the defense anticipates this response, then perhaps it should reassess its decision to defend primarily against running plays.

We are saying two things with this example. *First*, explanations for individual decisions that take the form “actor *i* chose action Y over Z because *i* preferred Y to Z” are not wholly satisfactory. Instead, we must consider propositions of the form “*i* chose Y because *i* believed that the other relevant actors, *j*, *k*, etc., would choose B, D, etc., and given these choices, action Y led to a better outcome for *i* than did other alternative actions. (Y is *i*’s best response to B, D, and so forth.)” Although this restatement may appear to be only a modest revision in our thinking, once we accept it, as our football example reveals, we must also understand that we cannot fully explain final outcomes until we utter a parallel statement for person *j* (as well as for every other relevant decision maker)—that *j* chose B because, if *i*, *k*, etc., choose

Y, D, etc., respectively, then B led to the best outcome from *j*'s perspective. The *second* implication of our example is that after formulating such sentences, we necessarily confront the problem of higher orders of thinking. If what *i* chooses is a function of what *i* thinks that *j*, *k*, etc., will choose, and if what *j* chooses is a function of what *j* thinks *i*, *k*, etc., will choose, and so on, then how does each decision maker resolve the problem that all decisions are determined simultaneously—that what *i* does depends on what he believes *j* believes about him, and so forth?

The relevance of game theory is that it seeks to disentangle this simultaneity and to discover the choices people might reasonably be expected to make in such contexts. That is,

Game theory models individual decision making when people's fates are interdependent, when people are aware of their interdependence, and when each person tries to accommodate his or her awareness and the fact that others are aware as well.

2. Our characterization of things political and subsequent examples serve to emphasize the importance of institutions and the necessity to understand how institutions influence individual actions. A legislator's vote is pivotal only if a specific voting rule is employed, and an issue, as well as the candidates' stands on it, is relevant to an election's outcome only if those who care about the issue are enfranchised to vote and if their votes can be pivotal. Even in international systems that we might model as being anarchic because they are governed by little more than the rule that nations with greater military capability can overcome those with less, if we want to understand why they remain anarchic—why various institutions are not used to regulate interstate action—we must attempt to understand the choices that people might be compelled to take if these institutions were to be implemented.
3. There is a final feature of our characterization of politics that is implicit in our previous examples—namely, that decision makers are goal directed. Before discussing this assumption in detail, however, we should first dispense with a potential ambiguity about the identities of these decision makers. Perhaps because of linguistic convenience, discussions of politics commonly refer to the actions that various groups or collectivities take and to the goals they pursue. However, language such as “interest groups lobby,” “the legislature

prefers," "the court decides," and "the union supports" commits the error of anthropomorphic reasoning. Groups and collectivities cannot act or choose. Actions may be taken in the name of groups, and the members of some collectivity may all have to act in concert for an action to gain the weight of group attribution, but only individuals can sign a check, push a voting lever, state a judicial opinion, or utter an endorsement. Of course, we too will find attributing actions to groups an irresistible linguistic convenience, but when succumbing to such conveniences we must keep in mind that ultimately the only valid explanation for a political event is one that explains the decisions of the individuals we judge germane to the event.

Having thus characterized politics as the study of individual interdependent choice in the context of institutions, the additional assumption that people's actions can be interpreted as directed toward the attainment of identifiable goals renders the rational choice paradigm the appropriate vehicle with which to study politics. Admittedly, though, attributing goals to people can be a difficult task. Goals are often obscure, such as when we do not understand fully the weights a Soviet premier places on long-term economic vitality, short-term national security, and personal survival or when we cannot judge when a legislator will act on the basis of a personally held policy preference as against the desire to be reelected. Similarly, we may have difficulty in understanding the goals of citizens who appear more likely to vote when elections are close than when they are land-slides, since the probability that a vote is decisive remains, for all practical purposes, zero in even close elections. At other times goals may be readily apparent, such as when we believe that an election candidate cares little about policy and is interested merely in winning, or when experience tells us that if corporate leaders fail to strive for greater profits, their jobs if not their firms will disappear.

Whether goals are obscure or self-evident, the assumption that goals motivate people's actions is the engine driving our explanations of political events, and it is this assumption that leads us to explore the applicability to politics of the formalism associated with the rational choice paradigm. However, given the difficulties that often accompany the identification of a person's goals, we should ask how we are to proceed with our analyses and modeling of politics. In addition, we should also ask how we can mute this criticism—that the assumption of goal-directed behavior verges on becoming a tautological explanation for events, since we can always assert that a

person's goal is to do precisely what we observe him or her to be doing.

The assumption of goal-directed action is given meaning by joining it to specific hypotheses about the content of goals. Because we want to explain as much as possible with as little as possible, one method is to conceptualize people in terms of the measurable things that might guide their actions. Thus, for legislators, we might assume that their primary objective is to win reelection and that policy preferences are secondary; for voters, we might assume that they are concerned solely with their personal income, or with some specific set of political issues; for international leaders, we might assume that they are motivated to increase their country's welfare, to maintain their nation's sovereignty, or simply to remain in power. As our models of specific processes mature, we can consider more complicated goals and allow for trade-offs between competing objectives. We can, for example, let legislators give some weight to personally held policy preferences as well as to the desire to be re-elected. And as we become more sophisticated in the construction of our models, we can try to determine which of our results depend on the details of goals and which results remain valid for more general descriptions about goals. We must always keep in mind, however, that formal theory gains substantive meaning only through the careful attribution of goals to the people whose actions we are modeling.

1.2 Essential Components of a Game

To illustrate the sorts of questions we must ask and answer as we try to understand specific political events, consider the following news item pertaining to the hostilities that arose between the United States and Iran in the Persian Gulf in 1988:

The precise rules of engagement [for U.S. naval forces] remain classified. [House Armed Services Committee Chairman] Aspen said it is necessary to keep the rules of engagement secret so the Iranians do not know which ships will be defended by U.S. forces and which will not be. "We are trying to deter the Iranians from violent action in the gulf . . . When they know what the rules of engagement are, they can work around them." (*The Los Angeles Times*, April 23, 1988)

Without delving deeply into the events surrounding this report, notice that we can evaluate the policy it describes only if we supply some additional facts. First, we must grapple with the fact that it is not "Iranians" who are to be deterred, but those who make decisions

about the deployment and actions of the Iranian military. It probably matters little if Iranian Kurds near the Soviet border feel deterred if, at the same time, no one in Teheran feels the same. Thus, we must ask: Who are the relevant decision makers, and what options for action are they likely to perceive—what actions are they likely to be deterred from and what actions will they presumably choose instead? Answering this question requires some understanding of Iran's domestic politics and the institutions mediating conflict there. Second, we should ask why the decisions of these Iranians might be expected to be a function of their information about U.S. rules of engagement. What features of American strategy are likely to intervene between Iranian actions and outcomes? This question can be addressed only if we understand the goals of those decision makers and how those goals are served by particular outcomes. We should also be concerned with the courses of action the Iranians perceive as being available to them. And, naturally, to fully understand this policy's logic, we must also understand the goals of those decision makers in Washington who established it, as well as their assessment of Iranian goals and the likely Iranian response to this and alternative policies. In short, then, an analysis of this situation requires, at a minimum, a specification of the following seven items:

1. A list of relevant decision makers,
2. The goals (policy objectives) of these decision makers,
3. The actions available to each decision maker,
4. A list of feasible outcomes,
5. The relationship between actions and outcomes,
6. The relationship between outcomes and goals,
7. Each decision maker's perceptions of items 1–6, as well as each decision maker's perceptions of the perceptions of others.

Finally, after having specified items 1–7 as they pertain to our example, we should determine whether or under what circumstances the implied ambiguity of U.S. policy can be unraveled by careful analysis. Can an Iranian strategic planner deduce the choice emanating from Washington, and can a strategic planner in Washington deduce the best choice for Iran, aware of the fact that his counterpart in Iran is doing the same?

All of the questions we have asked about this news item should occur to any competent strategic planner. What good policy analysis requires, though, is a general structure that forces us to these ques-

tions and ensures that we have not overlooked any important consideration. In other words, we require a structure that tells us "automatically" whether the linkages between goals, outcomes, alternative actions, and institutional constraints in an environment of interdependent choice have been adequately specified. Only then can we begin to answer the last question we posed concerning our prediction about actual decisions.

For another example that illustrates how we intend to proceed, consider the seemingly perpetual lament about the level of voter turnout in U.S. presidential elections. Time and again we are reminded that few citizens exercise their franchise, presumably because they fail to perceive great differences in policy between the candidates. The implication is that such perceptions and the accompanying low turnout are symptomatic of something wrong with our democracy. However, consider this argument: In large electorates, pluralities (the differences in vote totals between pairs of candidates) in even close presidential elections generally exceed tens of thousands of votes. Thus, the probability that any one vote is decisive is infinitesimal, if not zero. In addition, if the candidates fail to offer distinct policy choices and if voting is costly (in terms of time), then we should ask instead: Why do so many vote?

To answer this question, we must construct an election model that fills in the details of items 1–7. First, limiting our model initially to two-candidate elections, the relevant decision makers are voters and the two candidates. Second, each voter must vote for one candidate or the other, or abstain, whereas as an initial simplifying assumption, we can suppose that the set of actions available to each candidate consists of alternative policy promises. For purposes of constructing a "well defined" model, we can represent these alternative promises as points on a line that might correspond to a "liberal-conservative" or to a "left-right" continuum. Third, the goal of each voter, presumably, is defined in terms of the public policy that eventually prevails as a result of the election. Specifically, we can suppose that each voter has a most preferred policy and that the further one moves from this policy, the less satisfied that voter becomes. And, as an initial assumption, we can suppose that candidates are motivated primarily by the desire to win. Fourth, outcomes are denoted by the identity of the victorious candidate, in conjunction with some final policy. Fifth, the final outcome is determined, presumably, by the actions of voters and the choices of the candidates in the obvious way. Sixth, the extent to which each voter's goal is satisfied is a function of how "far" the policy advocated by the victorious candidate is from that voter's most preferred policy. Finally,

we can suppose that all voters and candidates are aware of this election scenario.

Having specified such a model, we can then address a variety of subsidiary questions: What is the relationship, if any, between individual decisions to vote (and, thus, turnout) and the actions of candidates and their parties? What is the relationship, if any, between a citizen's preference for one candidate or another and the citizen's likelihood of voting? Is it necessarily the case that it is in a candidate's interest to offer policy choices distinct from the opponent so that turnout might increase? Do our electoral institutions differ in systematic ways from the institutions of other countries so as to induce lower turnout either directly by their influence on citizens or indirectly by their influence on the strategies pursued by candidates and political parties? Do candidates and voters respond to our institutions in such a way that campaign platforms and public policy differ from those induced by systems in which nonvoting is fined or voting is subsidized? What assumptions are implicit in the presumption that low turnout is symptomatic of something amiss?

So, before we can draw any conclusions about the meaning of turnout rates, we must understand the interrelationships of electoral institutions, candidate campaign tactics, public policies implemented by incumbents, and citizen choices. And once again, the answers to such questions require that we explore the model constructed when we filled in the details of items 1–7 outlined previously.

1.3 The Extensive Form

Constructing a model of a particular political process in a way that allows us to apply what we learn from it to the study of other processes and events requires the development of some general conceptual constructs. This, in turn, suggests that we also require some convenient mathematical notation with which to represent those constructs. Beginning with what it is we want to explain—the actions of individuals—consider once again our example of conflict in the Persian Gulf. Since we have not yet presented the tools required to model domestic politics, suppose for the moment that a single decision maker, 1, sets Iranian policy, and that another such person, 2, chooses the U.S. action. Suppose person 1 can choose one of the following actions:

a₁: Do nothing

a₂: Attack non-U.S.-flagged shipping

a₃: Attack any target of opportunity, including U.S.-flagged shipping

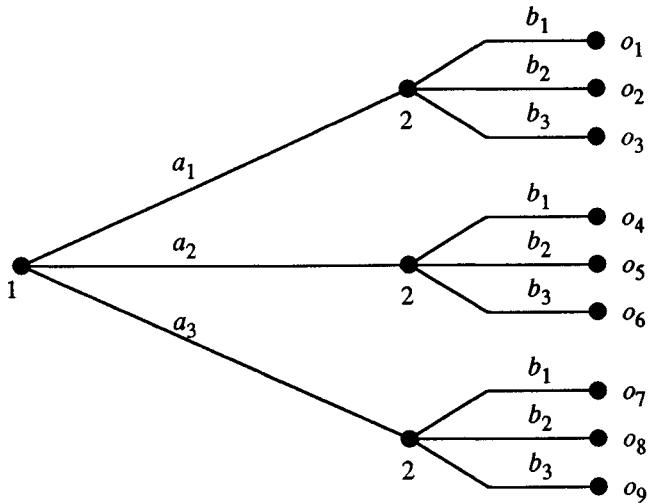


Figure 1.1 Persian Gulf Crisis Extensive Form

Suppose person 2 must choose one of these actions:

b₁: Do nothing

b₂: Attack Iranian ships

b₃: Withdraw

Because what one person decides may depend on what others do, we must identify the actual sequence of decisions and the outcome that follows from each feasible sequence. Presently, we have in mind a situation in which 1 moves first, and 2 responds to 1's initial choice. Figure 1.1 offers an especially convenient representation of this scenario, which we call **the extensive form**. Reading this figure from left to right, it states that 1 chooses first from the set of actions $\{a_1, a_2, a_3\}$, and then 2 chooses from the set $\{b_1, b_2, b_3\}$. Further, if person 1 chooses a_1 and 2 chooses b_1 , the status quo (denoted o_1) prevails and no shipping is harmed; if person 1 chooses a_1 and 2 chooses b_2 , we can assume that the Iranian navy suffers considerable damage but the United States is condemned by other nations (an outcome denoted by o_2); and so on. For convenience, we enumerate all possible outcomes by the notation o_1, o_2, \dots , and o_9 , and we leave it to the reader to imagine what outcomes o_3 through o_9 might entail.

It is not our intention yet to analyze this situation and to offer predictions about actions—in fact, our model is far too simple to yield meaningful implications. Rather, our purpose is to illustrate a

way to represent the situation that, upon refinement and elaboration, might prove to be a useful tool for arriving at substantively meaningful predictions or policy recommendations. We also want to demonstrate the flexibility of this approach for representing decision situations of considerably greater complexity. Hence, let us examine the four essential components of Figure 1.1, which are:

1. **Decision nodes**, which identify who it is that must decide at a particular stage in the decision-making sequence,
2. **Branches**, which connect one node to another, and which thereby indicate which decision node, if any, follows another as a consequence of the selection of a particular action,
3. A **labeling of lines** so as to denote the particular actions to which they correspond,
4. **Specification of the outcomes** that prevail after everyone acts

We impose two constraints on branches and outcomes. First, we do not want to leave open the possibility that people might act in ways disallowed by our model and we want to identify actions unambiguously, so we require that the branches radiating from any node correspond to exhaustive and exclusive alternatives. Exclusivity requires that one and only one branch (alternative action) can be chosen at each node. Requiring that actions are exhaustive assures us that decision making proceeds down at least one path toward a final outcome; requiring exclusivity assures us that at most one path is pursued, and, therefore, that only one outcome ultimately prevails. Second, the requirement that actions are exclusive and exhaustive implies that outcomes are also exclusive and exhaustive. Thus, if $O = \{o_1, o_2, \dots, o_n\}$ denotes the set of all outcomes portrayed in an extensive form, then at least one and only one outcome in O must ultimately prevail. Nodes labeled by an outcome are called **terminal nodes**.

At this point we note that, although our example fails to illustrate this possibility, one of the “decision makers” can be Nature. However, unlike a human decision maker, nature is not assumed to pursue any goal—it is neither deliberately malevolent nor benevolent, nor is it an entity that acts in anticipation of what other decision makers choose. Thus, decision nodes can be of two types:

1. Those denoting a decision point for one of the decision makers we have identified as relevant to the problem at hand,
2. Those representing random moves by nature, **chance nodes**

The branches from Nature's nodes are labeled p_1 , p_2 , and so forth to identify the probability that one branch or the other is "selected." Chance nodes can occur anywhere in an extensive form, but since nature's choices must also be exclusive and exhaustive, the sum of the probabilities assigned to the branches at any such node must equal 1.

In addition to allowing chance moves by nature, extensive forms need not be limited to representing the decision problem confronting two persons; nor are we required to suppose that decision makers can act only once in a situation. People can choose sequentially—first one, then another, then the first again—and, indeed, who chooses can be made dependent on the actions others take.

Example: Suppose each chamber (H and S) of a bicameral legislature consists of a single member (never let it be said that theorists do not know how to simplify a problem in the name of tractability) and that both legislators must pass a bill (choices p and f) before it goes to the president (P), who can approve (a) or veto (v) it. If the president vetoes, the two chambers must vote to override (o) or sustain (s) the veto. If we suppose further that H moves before S, Figure 1.2 portrays the extensive form of this situation. Notice that we allow chamber S to vote even though it knows that chamber H has already killed the legislation. This assumption, of course, allows us to accommodate the possibility that legislators treat the failure outcomes differently, depending on who can be held responsible for killing the measure. The U.S. Senate's passage of Contra aid in 1988, despite the House's prior rejection of the proposal, illustrates this possibility.

One possibility that we have not considered is that people choose in ignorance of what others have done. Referring to our Persian Gulf example, suppose the United States (player 2), prior to 1's initial decision, can secretly choose between increasing (c_1) and maintaining its current forces (c_2). Consider Figure 1.3's representation of this situation, which merely offers two versions of Figure 1.1, depending on 2's initial action. However, we have drawn a dashed "envelope" around 1's decision nodes to indicate that, since 2's first move is secret, 1 does not know which node it is at when it is time to act. No envelopes are drawn about 2's nodes, since 2 knows what secret action it took.¹ We refer to envelopes such as the one in Figure 1.3

¹To ensure a consistent mathematical notation, we can suppose that such envelopes surround all decision nodes but that some such envelopes merely encompass one node.

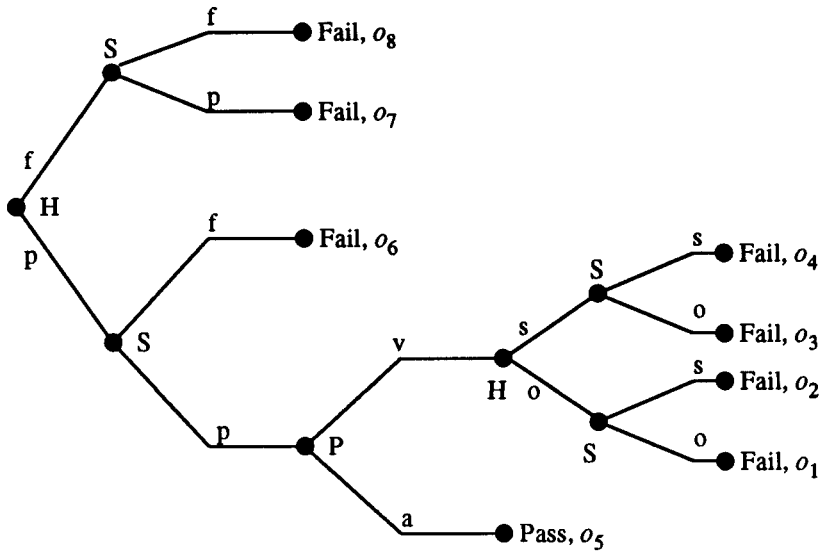


Figure 1.2 Legislative Extensive Form

as **information sets**, and we can not understate their importance. With them, for example, we can not only represent secret moves but simultaneous moves as well, or, equivalently, moves by several decision makers that remain secret for awhile. Suppose, for example, that our legislative example is modified to require that both chambers of the House always vote simultaneously rather than sequentially (admittedly, a curious and difficult requirement to implement). Figure 1.4 shows the modifications of Figure 1.2 required to represent this institutional change.

Notice that in the event of simultaneous or secret moves it should not matter who we identify as the first to act and who the last; we could just as easily suppose that S moves first and that the information sets in Figure 1.4 pertain to H's decision nodes. For the same reason the two extensive forms in Figure 1.5a and 1.5b are equivalent. Although 1.5a draws person 1's decision node first, and 1.5b draws person 2's first, the subsequent information sets model a situation in which neither player knows the choice of the other when it is that person's "turn" to choose.

In addition to secret or simultaneous moves, information sets allow us to model other diverse types of situations. For example, there is nothing in the rational choice paradigm that presupposes that decision makers have perfect memories. Thus, Figure 1.6a illustrates

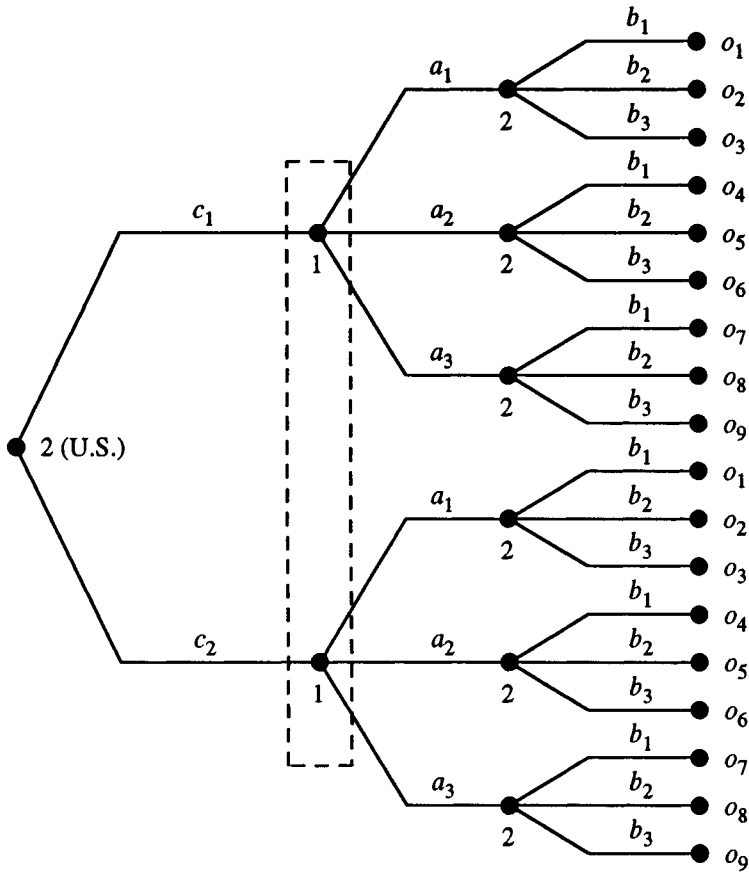


Figure 1.3 Expanded Persian Gulf Crisis Extensive Form

a situation in which persons 1 and 2 alternate in making binary choices, where each observes the choices of the other, but person 1 can only recall the last decision and person 2 can recall only the last two. Because 2 has the better memory, 2's information sets are more detailed and, thus, more numerous than are person 1's. For a final example of the flexibility that information sets allow, we note that the structure of a person's information can be modeled depending on the actions that person or others take as the situation unfolds. To illustrate this possibility, Figure 1.6b portrays a situation in which one person's information depends on what another person chooses. In this example, person 2 learns whether or not 1 chose a_1 , but if a_1 is not chosen, 2 cannot tell whether 1 has selected a_2 or a_3 .

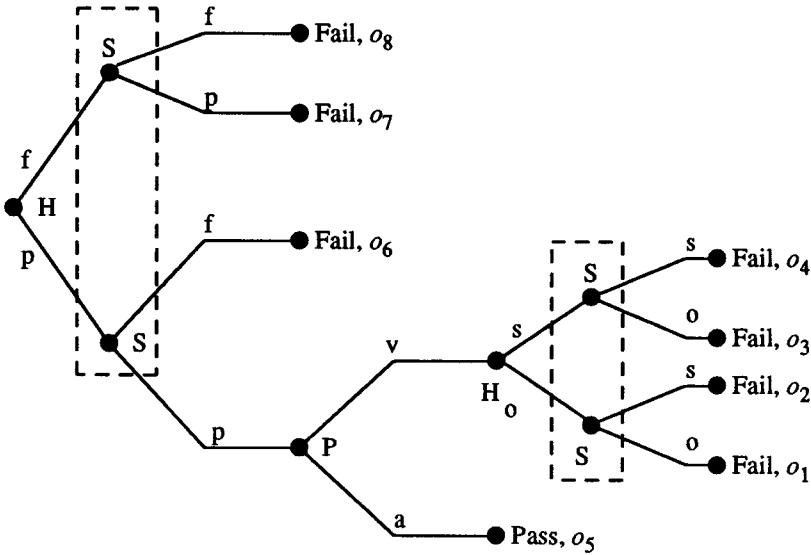


Figure 1.4 Legislative Extensive Form With Simultaneous Moves

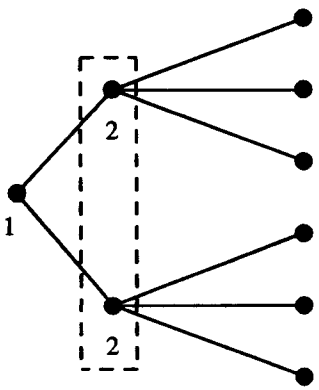


Figure 1.5a

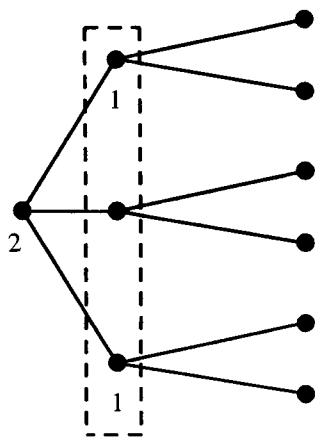


Figure 1.5b

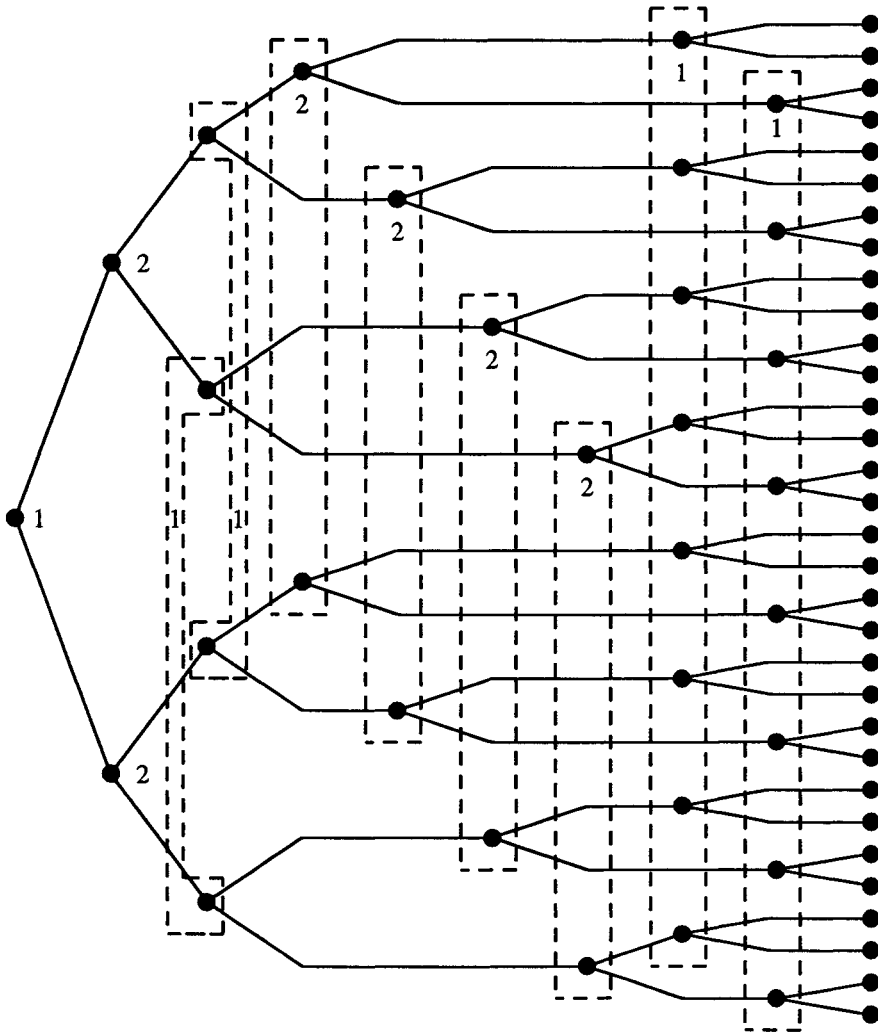


Figure 1.6a Extensive Form With Limited Memory

More generally, information sets allow us to distinguish between two general classes of interdependent choice situations—games with perfect versus imperfect information.

*In a game with **perfect information**, all information sets encompass a single decision node. Such games correspond to situations in which all decision making is sequential and all decision makers know the choices that they and others made any time in the past. In a game*

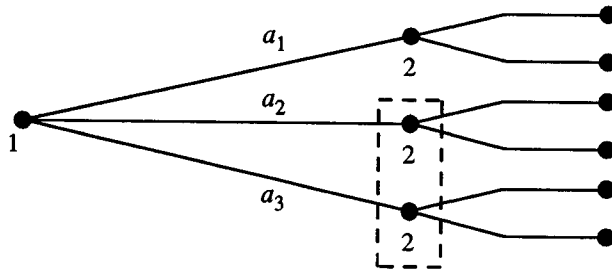


Figure 1.6b

with **imperfect information**, at least two decision nodes are in the same information set for at least one decision maker. Such games correspond to situations in which at least one decision maker is unaware of the choices made by another decision maker.

Although information sets increase the applicability of extensive forms, certain rules must be adhered to when we use them. Specifically,

1. All decision nodes contained in an information set correspond to the same decision maker. An information set describes what a decision maker knows about earlier decisions when it is his or her turn to act and, thus, each information set describes something about a specific person.
2. Each node in an information set has the same number of branches emanating from it; otherwise the decision maker can identify which node he or she is at by the number of alternative actions.
3. For the same reason, the labels attached to the branches at each node must be matched by the labeling of branches at any other node in the same information set.

Finally, we will impose two additional restrictions on extensive forms. First, we will suppose that the branches connecting nodes cannot “double back” to some previous node. Later we will accommodate the possibility that some branches may require that the people replay all or part of the game, such as when they fail to reach agreement in some bargaining session and must try again, until an agreement is reached. For now, however, it is easier to consider situations in which such possibilities are excluded. A second and related assumption is that all branches lead eventually to some outcome. That is, we suppose that the time allowed to play a game is

finite. As with repetition, we later consider situations that, in principle at least, allow for the possibility of infinite play.

1.4 Preference and Utility

The preceding examples of extensive forms merely scratch the surface of possibilities, and thus they do not reveal the ambiguities we will encounter as we use such forms to model various events and processes. However, before we explore some of these problems with additional examples, we must develop a notation for representing goals. After all, we seek to portray the alternative actions of people because we want to predict which choices follow from their goals, and to make such predictions we must find a convenient way to represent goals.

We begin with the assumption that goals manifest themselves as preferences over the outcomes that an extensive form identifies as feasible, and we use two more specific assumptions to summarize the logical form of preferences, regardless of the goals rationalizing them. First, we assume that preferences are **complete**. This assumption requires that for any two outcomes in the set O of outcomes thought to be feasible, a person either prefers one outcome to the other or is indifferent between them. That is, if given a choice between o_i and o_j , a person will either make a definitive choice or be indifferent. Second, and perhaps more controversial, we assume that preferences are **transitive**. That is, if o_i is preferred to o_j , and if o_j is preferred over or equally preferred to o_k , then o_i is preferred to o_k .

The assumption of transitivity, then, precludes the confusion that those of us, untrained in the subtleties of art, are likely to exhibit in an art museum. If required to state a preference between successive pairs of paintings, this author would almost certainly generate a great many intransitive choices. And, in addition to supposing that people cannot be confused, the assumption of transitivity supposes that people's perceptual abilities are perfectly formed—which is almost certainly not true in many situations. For example, if a person prefers unsweetened to sweetened coffee, then transitivity requires that that person prefer a cup of coffee with no sugar to a cup containing one grain of sugar, a cup containing one grain to a cup containing two grains, and so on. No one, though, is likely to be able to detect the difference of a single grain, so although indifference prevails across a long series of paired comparisons, transitivity is violated by the strict preference between the first and last alternatives.

Although we can imagine circumstances under which either the