Accuracy in Journalism: An Economic Approach

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THE CONCEPTION OF SOCIAL EPISTEMOLOGY

This chapter is part of a larger project to define and develop a certain nontraditional sector of epistemology—a sector dubbed "social epistemology." As traditionally pursued by philosophers, epistemology is the attempt to study, analyze, or guide the efforts of isolated cognizers, each of whom has the task of deciding, without fundamental dependence on others, what to believe about the world. The individualistic tradition in epistemology received its initial impetus from Descartes, who identified self-knowledge as the starting point of all knowledge. But even epistemologists who reject Descartes's starting point have typically agreed with Descartes in viewing epistemology as the theory of isolated, independent cognizers, each pursuing truth on the basis of evidence available to him or her as an individual. This individualistic conception does not wholly exclude other cognitive agents. The target agent can legitimately consider evidence gleaned from the utterances or speech acts of other people. Nonetheless, the perspective of traditional epistemology is emphatically individualistic: it studies almost exclusively the sorts of reasoning procedures available to the individual agent, with the aim of selecting the best of these procedures.

How might social epistemology differ from traditional, individual epistemology? One of the present authors (Goldman 1987b, also see 1986, 1987a, 1991a, 1994) has proposed the following conception of social epistemology. In addition to the reasoning and other psychological processes that influence agents in deciding what to believe, there are
various group processes and institutional arrangements that also influence belief formation. The proper domain of social epistemology, then, is the social processes and institutional provisions that standardly affect belief formation. Furthermore, just as it is widely held that individual epistemology should evaluate candidate reasoning procedures in terms of their tendency to lead reasoners to true rather than false beliefs, similarly social epistemology should evaluate various social processes and institutional arrangements in terms of their promotion of true rather than false beliefs. With the possible exception of pure science, there may not be any existing social processes or practices that are exclusively dedicated to the pursuit of truth, independent of other types of social values. But whatever the relative importance of true belief as compared with other kinds of social values, and whatever weight is placed on true belief by our current institutions, the distinctive role of social epistemology (as contrasted with social theory generally) is the assessment of the truth-conducive properties of sundry social practices. The pursuit of truth is not the be-all or end-all of social life, but it is the special proprietary interest of social epistemology.

SOME EXAMPLES

Some simple examples of social epistemology may help put some flesh on this rather abstract skeleton. As a first example, consider true or false judgments that are the product of group decision-making. For instance, committees can judge (or try to judge) what is the most efficient plan for achieving a specified institutional end. Or they can judge which of various candidates would turn in the best performance on a specified job, or in a certain course of study (e.g., a doctoral program). In some of these cases it may be problematic whether judgments have definite truth values. So consider a case where this is relatively unproblematic: weather prediction. A prediction today that it will rain in Tucson tomorrow has a definite truth value, although its truth will not be known with certainty until tomorrow. We ignore here borderline cases such as mist, and also the problem of whether there is a truth value today about tomorrow’s weather. At least we can say, once tomorrow has gone, that today’s prediction of rain either came out true or came out false. Admittedly, many weather predictions nowadays are made with probabilistic qualifiers, e.g., "There is a 20 percent chance of rain tomorrow." It is problematic whether such predictions can turn out either true or false. Assume, then, that weather predictions are made categorically, e.g., "It will rain tomorrow," or, "The high tomorrow will
be in the mid-80s [i.e., between 83 and 87])." Such predictions certainly qualify as true or false. Now, most weather forecasting is done by single weather forecasters. But consider a television station that assembles a team of weather experts and assigns them the task of collectively producing a local weather forecast. Supposing that they have different degrees of competence or expertise, ascertainable by looking at their individual past track records, how should the opinions of these several experts be pooled or weighted to arrive at the most accurate group judgment? This is one sort of problem in social epistemology.

This problem, in fact, is quite tractable. As Shapley and Grofman (1984) show, if individual judgments are mutually independent, and if each of the two choices (in our case, rain or nonrain) is a priori equally likely, then the best way to maximize the probability of the team's making an accurate prediction is to assign certain weights to each expert as a function of his or her individual competence. In other words, the most truth-conducive scheme is not majority rule with equal weights, nor dictatorial rule by the most competent expert (if a single forecaster has the highest competence), but a rule that assigns weights \( w_i \) in proportion to \( \log(p_i/(1 - p_i)) \), where \( p_i \) represents the probability that member \( i \) individually makes a true prediction. Suppose, for example, that there is a five-member team whose individual probabilities of correctness are: .9, .9, .6, .6, and .6, respectively. Then one way of assigning weights in conformity with this rule is: .392, .392, .072, .072, and .072. Assigning these weights and determining a group judgment by weighted voting would then generate a group competence (expected truthfulness) of .927. This is higher than the individual competence of any single member who might be chosen as dictator, but also higher than unweighted majority rule, which has a group probability of only .877. Thus, adoption of this sort of group judgmental practice might be a recommendation of social epistemology. (Its preferability, however, depends on the feasibility of determining accurately the individual competences of all members.)

A second set of examples will be drawn from judicial practices. Juries are prime examples of committees assigned the task of arriving at a group judgment, and presumably a principal desideratum of jury judgments is accuracy, e.g., judging an accused man to be guilty if and only if he is truly (genuinely) guilty of the charge(s) in question. Accuracy or truth is not the only desideratum of trial proceedings, but it is an important one and the one that interests social epistemology. Now, there are many institutional aspects of trial proceedings that seem to be dedicated, at least in part, to obtaining accurate verdicts. Among these are evidentiary rules governing the admission or exclusion of evidence. The rationale for these
rules is stated in Rule 102 of the Federal Rules of Evidence, which explicitly mentions the goal of truth: "These rules shall be construed to secure fairness in administration, elimination of unjustifiable expense and delay, and promotion of growth and development of the law of evidence to the end that the truth may be ascertained and proceedings justly determined" (emphasis added). One of the evidenciary rules, Rule 403, states in part: "evidence may be excluded if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury." If this rule is indeed rationalized by reference to the aim of truth (see Goldman 1991a), then it is appropriate for social epistemology to inquire whether such a rule actually promotes accuracy just as well as competing rules that might be substituted in its place. This is an example of how social epistemology is concerned with institutional provisions that bear on truth acquisition. Other such examples in the law might include rules for jury selection, the privileged attorney-client relationship and advocacy responsibilities, and so forth.

A third example of the domain of social epistemology concerns the topic of argumentation. Goldman (1994) defends the view that social argumentation is governed by tacit rules that are dedicated to the goal of advancing true belief, either for the arguers themselves or for their audience. Part of social epistemology is the elucidation of these rules and the examination of them to see whether they are indeed truth conducive. Assuming that they are so conducive, another recommended task for social epistemology is to explore the variables that influence the extent and quality of argumentation, i.e., the frequency or infrequency with which serious disputation takes place in formal or informal contexts, and the quality of such argumentation, i.e., the degree to which the rules of good argumentation are actually instantiated.

This last task is one to which social scientific models, e.g., rational choice models, can make an important contribution. An example of this is the work of Michael MacKuen (1990), who provides a game-theoretic analysis of decisions to engage in face-to-face political argumentation. The paradigmatic situation MacKuen examines is that of a citizen encountering an acquaintance in an elevator during an election campaign. Will our first citizen initiate a political conversation, or will he be deterred by recalling that the last time he made a political comment his interlocutor called his ideas "foolish" and smugly wandered down the hall? The incidence and extent of political interaction—especially argumentation with people of differing opinions—is widely regarded as significant for democracy. But MacKuen's analysis suggests that the strategy of CLAMMING (avoiding political argumentation) is much more
likely to be chosen than TALKING (arguing), so MacKuen is highly pessimistic about the prospects of cross-factional political debate. To the extent that cross-factional argumentation is helpful for truth acquisition, a low incidence of such argumentation is (or would be) a matter of concern to social epistemology. And the variables that influence this incidence should also be of concern to social epistemology, from both a theoretical and a policy perspective.

JOURNALISM AND SOCIAL EPISTEMOLOGY

In this chapter we focus on journalism as a special target of social epistemological study. Traditional epistemology would most naturally address journalism solely from the vantage point of the reader: what inferences can or should a reader make from stories in a newspaper? Our perspective will be somewhat different. We shall ask about the variables that affect the truthfulness or accuracy of stories that get printed in newspapers (or presented on television). We recognize, of course, that readers need not believe everything they read or see, but we shall assume that the default procedure, at least, is to believe what one reads (or sees). Hence, people will suffer from erroneous belief, or misinformation, if newspapers in fact present falsehoods (or half-truths). What are the factors, then, that influence the truth value of what is printed in newspapers?

Some other preliminary comments are in order. It goes without saying that newspapers print much that does not fall in the category of "news," and that what motivates readers is not exclusively an interest in truth. Readers often read for entertainment, where the "facts" are immaterial. For purposes of present discussion, however, we restrict attention to news, and to truth-related interests. We do not deny the existence of non-cognitive interests, but we also believe that readers are substantially and sincerely interested in truth. They expect the sports pages to report correctly the outcomes of games, and to provide accurate statistics. They want coverage of crime in their neighborhood to be accurate, and they expect announcements of the times and locations of movies and cultural events to reflect the facts. They would be quite unhappy with faulty stock market reports, and similarly for other news of business developments. Even when it comes to official corruption or the sexual escapades of political figures, they are not interested in sheer fantasy. Though they may prefer titillating stories to less colorful items, they would not be (so) interested if the stories were known to be spun out of whole cloth. There may be some kinds of things that readers prefer not
to know about, but they read newspapers in large part with the hope of learning selected facts. Notice that our claim of a substantial interest in truth is not essential to social epistemology. Social epistemology could conduct an inquiry into the factors affecting the accuracy or objectivity of journalism even if readers themselves had little or no concern for truth. But in this chapter we shall assume that truth acquisition is a major goal of readers.

Admittedly, the concepts of truthfulness and objectivity, especially concerning the news, are concepts very much in dispute. Although it would be impossible to allay all relevant worries about these concepts, some remarks may help defuse some of these worries. At a minimum we can identify where we stand (or at least where the philosopher-author, A.G., stands) on these issues. One set of worries about the concept of truth is abstractly philosophical. Is the concept of truth to be defined or understood independently of the possibility of human verification, or does it depend essentially on verificational possibilities? We take a "realist" position on this issue. The concept of truth allows for the possibility of certain propositions being true—in other terminology, of there being certain "facts"—even if these facts are in principle unknowable or unverifiable by human beings. For example, there may be facts beyond our ken because they concern matters at some distant corner of the universe, spatio-temporally too far removed from human detection during the whole of humankind's sojourn at this corner of the universe. In addition to distinguishing truth from the possibility of human detection, it is particularly important to distinguish truth from actual human detection. There are presumably many truths that are unknown to any human beings. These may include, for example, what particular kinds of fish, if any, are swimming at a particular spot in the ocean depths at a particular time. Such a fact may indeed be unknown to any human, but that doesn't mean that it isn't a truth. It is important to separate the concept of truth from the concept of knowledge because the acknowledged difficulties in settling when people have knowledge should not be allowed to undermine the concept of truth itself. When people disagree, and when evidence conflicts, it is difficult to tell, or know, where the truth lies. But that does not imply that there is no truth of the matter, however uncertain, or subject to dispute it may be. Of course, not every factual-looking sentence may be the kind of sentence that has a truth value (i.e., truth or falsity). Sentences concerning morals and normative politics are prime examples of sentences often said to lack a truth value. We take no stand on this issue. What we do assume is that many of the matters reported in news stories do have truth values, and it
is their truth values that we shall be addressing. The full range of truth-valuable sentences need not be settled here.

In point of fact, we are not just interested in the truth values of the sentences actually printed in news stories (or reported on television or radio). Even if all such sentences are true, they may be (seriously) misleading in the sense that they lead large segments of the readership or audience to infer other statements that are false. To take a simple example, a news story may report: "Yesterday official $O$ asserted $p$." If $O$ is a highly credible source for most of the readership, they will infer not only that $O$ asserted $p$ but that $p$ is true. Suppose, however, that $p$ is false. Since the story does not assert $p$, it does not literally contain anything false. But it does promote a false belief in (much of) its readership, and in that sense is misleading. (In the sense used here, obviously, misleadingness need not be deliberate.) Similarly, an incomplete and/or slanted news story may distort the facts not in the sense that it says literally false things but in the sense that it leads readers to draw further conclusions that are false. The accuracy of journalism should be measured not simply by the truth of the sentences it prints, but by the degree of its misleadingness or nonmisleadingness.

Many, perhaps most, academic treatments of journalism take a very skeptical or cynical view of the media's capacity or disposition to depict reality accurately. This is clearly reflected in numerous book titles dealing with the news, e.g., *The News: The Politics of Illusion* (Bennett 1983), *Making News: A Study in the Construction of Reality* (Tuchman 1978), *Inventing Reality: The Politics of the Mass Media* (Parenti 1985), and *The Manufacture of News* (Cohen and Young 1981). A pervasive theme in media analysis is that the media are engaged in "constructing" reality, which strongly intimates that they cannot be "reporting the truth." It is essential, however, to distinguish two senses of reality "construction." In one sense, constructing reality might consist in literal fabrication or invention of news, i.e., the reportage of items that never occurred, or never occurred in the manner described. This sense of construction or fabrication straightforwardly implies falsity. A second sense of "reality construction," however, merely refers to the selection or choice of events to report from a vast flux of daily occurrences. It refers partly to the fact that media managers have categories they regard as important, newsworthy, or appealing to their audience, and they choose events and design media presentations in conformity with these categories and criteria. This second sense of reality construction, however, does not straightforwardly imply falsity. The selection of bits of reality from a welter of alternatives does not necessarily involve untruths or distortion,
unless such selection is misleading in the sense specified earlier. So even if we grant that media managers "construct" reality in the second sense, we need not necessarily despair of truthfulness in the news.

Let us now turn to some of the practices and institutional structures in journalism that invite treatment from social epistemology. It may help to introduce some of this material with the help of an infamous journalistic incident.

Jimmy is 8 years old and a third-generation heroin addict, a precocious little boy with sandy hair, velvety brown eyes and needle marks freckling the baby-smooth skin of his thin brown arms. . . . His hands are clasped behind his head, fancy running shoes adorn his feet and a striped Izod T-shirt hangs over his thin frame. "Bad, ain't it," he boasts to a reporter visiting recently. "I got me six of these."

So began an article by Janet Cooke on the front page of The Washington Post on Sunday, September 28, 1980. (See Goldstein 1985, pp. 215 ff., for details.) The reporter Cooke was promoted from a weekly suburban section to the far more prestigious metropolitan section. Washington Mayor Marion Barry, Jr., ordered police and social service agencies to find the boy. When police threatened to subpoena Cooke in an effort to force her to reveal the names and addresses of her sources, the Post supported her in resisting the issuance of the subpoena. Red flags were subsequently hoisted within the Post itself, as Cooke seemed to be unacquainted with the neighborhood where Jimmy was supposed to live. Nonetheless, the editors submitted the story for the Pulitzer Prize, which it won the following April. Unfortunately, things started to unravel soon thereafter. It turned out that Cooke had falsified her credentials on her resumé. She said she was an honors graduate of Vassar; in fact, she had dropped out after a year and finished up college at the University of Toledo. After Cooke confessed about this lie, she was interrogated by Post editors for several hours and finally admitted that she had fabricated the Jimmy story as well as her resumé. In a survey done three years after the Janet Cooke scandal, the ethics committee of the American Society of Newspaper Editors found it had become a general rule among newspapers that a reporter must share with an editor the identity of a confidential source.

This story conveniently introduces four principal types of agents or actors that are relevant in the analysis of journalism: (1) readers, (2) reporters, (3) editors, and (4) sources. Readers read stories in newspapers to acquire new knowledge or information, i.e., new truths. Their success in this endeavor, however, depends on the stories' they read being true.
However, one of the principal actors in the construction of such stories, viz. reporters, have some incentives for fabrication. Obviously, not all stories are of equal interest to the readership, nor of equal interest, therefore, to editors. Stories that are highly "newsworthy" (whatever exactly that amounts to) are of greater interest to the readership, and are therefore of greater value to reporters, since their production can lead to promotions, higher pay, and even Pulitzer Prizes. Editors also have an interest in publishing highly "newsworthy" stories, but they can also suffer if their newspaper earns a reputation for fabrication or exaggeration. Thus, they have a professional interest in ensuring the accuracy of their reporters' stories.

The fourth type of actor, the source, is purely imaginary in the Janet Cooke incident. But most stories (especially those involving politics) typically involve a source or informant as the reporter's basis of the story. Here too we have two actors with frequently divergent interests. The source may want the public or some other actors on the political scene to believe certain things which in fact are untrue, or only a partial truth. Thus, what he or she tells a reporter has a certain probability of being (wholly or partially) false. In other language, the source may wish to get out a story with a certain "spin" that is favorable to his or her political interests. The reporter, on the other hand, does not wish to publish a story (under his or her byline) that will subsequently be revealed as erroneous or misleading. Yet the reporter may need to cooperate with the source, at least to some extent, if he or she is going to continue to receive stories from that source. Some sources are extremely valuable to a reporter by virtue of their position and "inside" knowledge. Thereby arise some noncoinciding interests between sources and reporters, which affect what sources tell reporters and what stories reporters subsequently write.

AN ECONOMIC APPROACH TO INFORMATION ASYMMETRIES IN JOURNALISM

Much of modern economic theory is concerned with developing models that include information asymmetries. The appeal of this type of model is obvious: it will often be the case that some important kinds of information are inherently private, not public information. Some illustrative examples would be these: the quality of a used car may be known by the prospective seller but not known by the prospective buyer; the productivity of a prospective new employee may be known by the worker but not known by the employer; the risk attitude of one's opponent in a game of strategy may be known by the opponent but not
known by oneself; and the limit price of the other party in a wage or price bargaining game may be known by the other party but not known by oneself. It seems natural to explore the possibility that adaptations and/or extensions of economic models of information asymmetries might be applicable to some questions that arise in studying journalism. The present chapter begins that exploration.

There appear to be various information asymmetries in journalism. One type of information asymmetry would seem to be a necessary condition for the very existence of journalism: if journalists cannot credibly claim to know some things that are not common knowledge, then they have nothing to sell. We shall explain that other, more subtle information asymmetries can be important determinants of the truthfulness or accuracy of stories that get reported by journalists.

Two simple models are developed in the next two sections of the chapter. One model analyzes the role that editors might play in establishing accuracy standards in journalism. This model focuses on the implications of readers’ not being able to know individual reporters by their reputations for accuracy. In that case, what are the implications of there being low-accuracy and high-accuracy reporters in journalism? Will there be a pooling equilibrium in which readers do not know whether they are buying low- or high-accuracy stories? Or will there be a Gresham’s Law for journalism in which low-accuracy reporters drive high-accuracy reporters out of the business, with the result that readers are only able to buy low-accuracy stories? Or will there be a separating equilibrium in which low-accuracy and high-accuracy reporters self-select into a two-tier journalistic market in which readers can knowingly choose to buy low-accuracy or high-accuracy stories? What role might editors play in this reporter self-selection process? As we shall see in the next section, the answer is that editors can establish editorial standards that make a separating equilibrium feasible.

The second model is concerned with the relationship between sources and reporters. It focuses on the case of a single source and a single reporter. A question of central interest in studying truthfulness in reporting is identifying conditions under which the source can control how the reporter writes the story after the source gives his or her information to the reporter. If the source has no ability to reward or punish the reporter, then the source has no control. Suppose, instead, that the source can reward or punish the reporter by, say, granting or withholding future favors. Then, if the source can observe the reporter’s choice of action, the outcome is transparent. If the source can offer the reporter sufficient reward, and prefers to do so, then the source can
control how the reporter chooses to write the story. This case is analytically trivial. The interesting case is one in which the source cannot observe the reporter's choice of action. Suppose that the source can read the story and learn whether it is relatively favorable or unfavorable to his or her interests, but that the source cannot know whether the favorable or unfavorable content resulted from the reporter's choices or from decisions made by the editor, the publisher, or some other actor. Under what conditions would the source be able to control the reporter's action even without observing it? The answer, provided by the model developed in the section on sources and reporters, involves a concept from statistics known as the "monotone likelihood ratio property." As we shall see, if the likelihood that the reporter chose an action favorable to the source's interests is a monotone-increasing function of the source's utility payoff from the story, then there exists a system of rewards that would make it possible for the source to control the reporter's choice of action even without observing that choice. This outcome can be problematic for accuracy in journalism because it makes a reporter's choice between more truthful and less truthful reporting subject to control by the source.

EDITORS AND REPORTERS

Assume, for simplicity, that there are two types of reporters. One type of reporter produces high-accuracy stories, each of which has value $v_h$ to readers. The other type of reporter produces low-accuracy stories, each of which has value $v_l$ to readers. We assume that low-accuracy stories have positive value and that high-accuracy stories have higher value: $v_h > v_l > 0$.

Assume that there are so many reporters that readers cannot know them individually by reputation. In that case, a reader cannot know at the time of purchase whether an individual story has high or low accuracy. Let $\pi_h$ be the proportion of high-accuracy reporters in the population of reporters. Also assume, for simplicity, that all reporters write the same number of stories; hence $\pi_h$ is also the proportion of high-accuracy stories in the population of stories so long as high-accuracy reporters remain active.

If both high- and low-accuracy reporters are active, then the expected value of a story is

\[ V = \pi_h v_h + (1 - \pi_h) v_l. \]
Thus, so long as readers cannot know the reputations for accuracy of individual reporters, the most that they will be willing to pay for an individual story is \( v \) (unless they are risk preferring). If stories sell for \( v \), then the high-accuracy reporters will be paid less than the value of their stories and the low-accuracy reporters will be paid more than the value of their stories. Furthermore, no reader can ever be assured in advance that a particular story has high accuracy. Finally, this outcome is the best of the possible outcomes for the present case because it is based on the assumption that high-accuracy reporters are willing to sell stories that are worth \( v_h \) for a price of (at most) \( v < v_h \). However, if high-accuracy reporters can earn \( v_0 \) in their best alternative employment, and if \( v < v_0 \), then high-accuracy reporters will exit. In that case, all available stories will be low-accuracy ones with value \( v_1 < v \).

We now introduce a third type of agent, known as an "editor." We assume that there are few enough editors so that readers can know individual editors by their reputations. Reporters can work with editors that impose various editorial standards. The function of editors is to certify to readers the editorial standard for accuracy, \( e \), that is met by stories written by their reporters. We assume that editors cannot check every (alleged) fact in every story for accuracy, but that they can check on the procedures followed by their reporters and certify that the procedures are appropriate for an editorial standard \( e \).

Let \( c_i \) be the constant marginal effort cost per story to a low-accuracy reporter of meeting editorial standard \( e \), where \( e \geq 0 \). Similarly, let \( c_h \) be the marginal effort cost per story to a high-accuracy reporter of meeting editorial standard \( e \). Assume that it requires more effort for a low-accuracy reporter to meet any editorial standard than it does for a high-accuracy reporter to meet the same standard; i.e., assume that

\[
(2) \quad c_i > c_h > 0, \text{ for all } e \geq 0.
\]

Finally, let \( \theta \) be the amount that an editor deducts from the value of a story before paying a wage to a reporter; that is, \( \theta \) is the compensation of editors for their services.

We will identify conditions under which there exists a separating equilibrium. Let \( \alpha > 0 \), and consider the following wage scale for reporters:

\[
(3) \quad w(e) = \alpha \begin{cases} 
  v_h - \theta & \text{for } e \geq e^* \\
  v_1 - \theta & \text{for } 0 < e < e^* \\
  v_1 & \text{for } e = 0.
\end{cases}
\]
Under this wage scale, any reporter who works with an editor that certifies an editorial standard of e* or higher will be paid a wage that is proportional to the value of a high-accuracy story less the editor's compensation. The proportionality factor, α, is the average number of stories per unit of time that a reporter writes. Similarly, reporters who work with editors that certify positive editorial standards below e* will be paid a wage that is proportional to the value of a low-accuracy story less the editor's compensation. Finally, reporters who do not work with editors will be paid a wage that is proportional to the value of a low-accuracy story.

Next, assume that

\[0 < \theta < v_h - v_l,\]

and recall that \(v_h > v_l\). Let e* be some positive real number such that

\[
\frac{v_h - v_l - \theta}{c_h} > e^* > \frac{v_h - v_l - \theta}{c_i}.
\]

We know that such an e* exists because \(c_i > c_h > 0\) and \(v_h - v_l - \theta > 0\). We will show that statements (3)-(5) imply the following equilibrium editorial standards for low- and high-accuracy reporters:

\(e_i = 0; e_h = e^*\).

There exists a separating equilibrium if each type of reporter prefers its own wage and editorial standard to the wage and editorial standard preferred by the other type of reporter. But this follows immediately from statements (3)-(6) because

\[
e^* > \frac{v_h - v_l - \theta}{c_i} \rightarrow c_i e^* > v_h - v_l - \theta
\]

\[
\rightarrow v_i > v_h - \theta - c_i e^*
\]

\[
\rightarrow w(0) - \alpha c_i 0 > w(e^*) - \alpha c_i e^*
\]

and
\[
\frac{v_h - v_l - \theta}{c_h} > e^* \quad \Rightarrow v_h - v_l - \theta > c_h e^*
\]

(8)

\[
\Rightarrow v_h - \theta - c_h e^* > v_l
\]

\[
\Rightarrow w(e^*) - \alpha c_h e^* > w(0) - \alpha c_h 0.
\]

Therefore, reporters can self-select in the following way. High-accuracy reporters can choose to work for newspapers that impose editorial standard \(e^*\); these reporters will be paid a wage of \(w(e^*) = \alpha (v_h - \theta)\). Low-accuracy reporters can choose editorial standard \(0\); these reporters will be paid a wage of \(w(0) = \alpha v_l\).

Under what conditions can such a separating equilibrium be attained? It is necessary that each type of reporter prefers its own wage and editorial standard to the one preferred by the other type of reporter. Statements (7) and (8) show that these necessary conditions are satisfied by the wage scale (3) and the editorial standards \(e_i = 0\) and \(e_h = e^*\) if statement (4) is satisfied. Statement (4) places an upper limit on the compensation, \(\theta\), that is paid to editors: \(\theta < v_h - v_l\); i.e., an editor cannot be paid more per story than the difference in value between high- and low-accuracy stories. Two other necessary conditions are as follows:

\[
\frac{1}{\alpha} w(e^*) - c_h e^* = v_h - \theta - c_h e^* \geq v; \text{ and}
\]

(9)

\[
\frac{1}{\alpha} w(e^*) - c_h e^* = v_h - \theta - c_h e^* \geq v_0.
\]

Condition (9) is necessary because, if it is not satisfied, then high-accuracy reporters prefer not to work with editors and, instead, sell their stories at the average story-accuracy price, \(\bar{v}\). Condition (10) is necessary because, if it is not satisfied, then high-accuracy reporters prefer not to work with editors and, instead, exit from reporting. Both (9) and (10) place restrictions on the amount of compensation, \(\theta\), that can be received by editors.

The separating equilibrium in editorial standards realizes the consumer and producer surplus from transactions in high-accuracy stories; however, it produces less social surplus than would be attainable if readers could know individual reporters by their reputations for high or low accuracy. The reason for this is that editors must be paid part of the value of high-
accuracy stories even though they neither write stories nor add to the quality of high-accuracy stories. The only role that editors play is in establishing editorial standards that make it feasible for high- and low-accuracy reporters to self-select into a two-tier journalistic market.

**SOURCES AND REPORTERS**

We have noted above that a reporter may not always be interested in truthful reporting because a story that contains some false information or some half-truths may be more newsworthy than a factually more accurate story. We have also noted that reporters may differ in their individual capacities for accuracy. These questions will not be discussed in this section. In order to focus on analyzing conditions under which sources can control how stories are reported, we will here assume that reporters are only interested in truthful reporting.

Reporting of political news is often dependent on information provided by sources with insider information. Such sources are often not simply interested in making information public but, instead, have an interest in having the information that they provide reported in ways that promote the source's objectives. Such reporting may or may not be truthful. Analysis of the relationship between sources and reporters is trivial in the case where both types of agents want all valid information to be accurately reported. In contrast, the case where reporters are interested in truthful reporting, but sources are interested in having readers misled in certain ways, is an interesting one to analyze. Our analysis will focus on the basic question of identifying conditions under which it is possible for a source to control how the reporter uses the information provided by the source.

There are many aspects to the informal contractual relationship between sources and reporters. For some types of news, there may be many sources competing with each other; for other types of news, there may be a single source with a monopoly on the relevant insider information. Analogously, there may sometimes be a single reporter, and at other times many reporters competing for the same source or sources. We will here analyze one of the possible relationships between a source (or sources) and a reporter (or reporters). We will study the relationship between a single source (with a monopoly on the relevant insider information) and a single reporter (with a monopoly on reporting this specific information). A famous example of this type of relationship is provided by the Deepthroat source in the Watergate scandal, and the reporter Bob Woodward.
A question of central interest in analyzing the bilateral monopoly relationship between a single source and a single reporter is identifying the conditions under which the source can control how the information is reported after it has been revealed to the reporter. Consider the case where, after obtaining the information from the source, the reporter can choose between writing a story that is more truthful (taking action m) and writing a story that is less truthful (taking action l). An example of a reporter’s "more truthful" action is one in which the reporter not only writes up what the source says but, in addition, seeks "balance" or "objectivity" by reporting related information.

The action chosen by the reporter does not completely determine the payoffs from the newspaper article to either the source or the reporter. There are several reasons for this. One reason is that the content of the article may be affected by actions chosen by the editor in addition to the reporter’s action. The editor may insist on modifying the reporter’s initial draft in certain ways, e.g., by adding or interpolating material that disputes or contradicts the source’s statements. Another route to the same effect is to publish conflicting material either in another story on the same page or on the editorial page. Such decisions are in the hands of the editor, rather than the (initial) reporter. The payoffs also depend on what statements have been publicly or privately made by other credible principals during the same time period, which is outside the control of either the reporter or the editor. The payoffs from the reporter’s article may also depend on whether it appears on page one or on some other page. Other things which may affect the impact of an article, and hence the payoffs to the source and to the reporter, include day of the week and season of the year in which it appears, whether or not Congress is in session, and so on.

Since the reporter’s action does not completely determine the payoffs to the source, an important consideration in determining the source’s ability to influence the reporter’s choice of action is whether or not the source can observe that choice. Subsequent analysis will be divided into two parts which differ in terms of an assumption that the source either can or cannot observe whether the reporter chose to write a more truthful or a less truthful story. As we shall see, the source’s ability to influence the reporter’s choice without observing it depends on the existence of a regularity condition from the literature on statistical hypothesis testing.

An example that illustrates some of the preceding points is provided by a 1965 story by Tom Wicker in the *New York Times* that was published during the period in which the U.S. government was beginning
to increase the level of troop commitment in Vietnam. Wicker's story contained the following:

President Johnson does not now intend either to halt the United States air attacks on North Vietnam or to move American combat troops into the forefront of a stepped-up antiguerilla war in South Vietnam.

Despite widespread speculation that many more American soldiers would soon be shipped to Vietnam, high officials here insist that no decision along those lines has been made. (Quoted from Hallin 1986, p. 96)

Obviously the second quoted paragraph undercuts the statement of the official source (Robert McNamara), though it says nothing about the basis of the "widespread speculation." Inclusion of the second paragraph produced a story that was more truthful than a story that excluded this paragraph. If the second paragraph was included because of a decision made by the reporter, this would provide an example of a reporter's choosing to write a more truthful rather than a less truthful story. Presumably, the source was not pleased by the inclusion of the second paragraph. But could the source know whether the inclusion of this paragraph resulted from the reporter's choice or from a choice made by the editor?

The effect on payoffs of the many things that neither the source nor the reporter can control is represented by a random component in payoffs. Thus the action chosen by the reporter does not determine certain payoffs; instead, the reporter's action determines probability distributions of returns for the source and the reporter. Let \( u_i \) be the utility payoff for the source if state of the world \( i \) occurs, where \( i = 1, 2, \ldots n \). Similarly, let \( v_j \) be the utility payoff for the reporter if state \( i \) occurs. A "state of the world" is defined by a specification of all outcomes from reporting a story that matter to the source and the reporter, including the reactions of readers, voters, professional peers, employers, and so on.

Define \( p_{im} \) as the probabilities that the states occur if the reporter chooses action \( m \). The probabilities that the states occur if the reporter chooses action \( 1 \) are denoted by \( p_{il} \). Assume that the state probabilities have the usual properties of probabilities: \( p_{im} \geq 0, p_{il} \geq 0, i = 1, 2, \ldots n, \) and

\[
\sum_{i=1}^{n} p_{im} = \sum_{i=1}^{n} p_{il} =1.
\]
From the assumption that the reporter prefers more truthful reporting, one has

\[(11) \sum_{i=1}^{n} p_{am} v_i > \sum_{i=1}^{n} p_{d} v_i.\]

If action \(m\) is also preferred by the source, then there is no reason for the source to attempt to control the reporter’s action. We will analyze the case where the source prefers that the reporter choose action 1 and the reporter prefers action \(m\).

Assuming that the source prefers action 1 to action \(m\) means

\[(12) \sum_{i=1}^{n} p_{u} u_i > \sum_{i=1}^{n} p_{im} u_i.\]

If the source has no ability to reward or punish the reporter after giving information to the reporter, then statement (11) implies that the reporter will write a more truthful article (choose action \(m\)). We will consider the situation where the source does have the ability to reward or punish the reporter. There are two cases to consider, depending on whether the source can or cannot observe the action chosen by the reporter.

Suppose that the source can observe the reporter’s choice of action and has the ability to reward the reporter. In that case, the choice of action by the source is transparent. The source can simply incur a utility cost \(c\) to provide the reward \(\psi (c)\) to the reporter (where \(\psi (\cdot)\) is a strictly increasing function) such that

\[(13) \sum_{i=1}^{n} p_{a} v_i + \psi (c) = \sum_{i=1}^{n} p_{im} v_i.\]

Any reward slightly larger than \(\psi (c)\) will cause the reporter strictly to prefer action 1 to action \(m\). The source may not choose to reward the reporter sufficiently to induce the reporter to take action 1, even given the ability to do so. If
(14) \[ \sum_{i=1}^{n} p_i u_i - c < \sum_{i=1}^{n} p_{m_i} u_i, \]

then the source would prefer the reporter's more truthful report to the combination of the reporter's less truthful report and the cost of the minimum reward needed to induce the reporter to choose action 1. Given (12)-(14), the source's decision would depend on the size of the payoff from the best alternative to dealing with the reporter, as represented by the source's reservation utility, \( \bar{u} \). If

(15) \[ \sum_{i=1}^{n} p_{m_i} u_i < \bar{u}, \]

then the source would prefer to withhold the information from the reporter. On the other hand, if

(16) \[ \sum_{i=1}^{n} p_i u_i - c > \sum_{i=1}^{n} p_{m_i} u_i, \]

and

(17) \[ \sum_{i=1}^{n} p_i u_i - c > \bar{u}, \]

then the source would prefer to incur a cost of \( c \), or slightly higher, in order to induce the reporter to choose action 1.

The really interesting case to examine is the one where the source cannot observe the reporter's choice of action. Thus we here assume that the source can read the article and judge whether its content is relatively favorable or unfavorable, but that the source cannot observe whether the article's contents have resulted from decisions made by the reporter or by the editor. We also here assume that the source cannot observe the reporter's influence over other things that affect the source's utility payoffs from the article, such as the page on which it appears and the location and content of other related articles that could influence the source's payoffs. Thus we here assume that the source can only attempt to infer the reporter's choice of action from the payoffs that the source
obtains from the article. If that is the case, then under what conditions is it possible for the source to implement a reward plan (informal contractual arrangement) that can influence the reporter’s choice of action? We will next analyze this question.

Let \( c_i \) be the source’s cost of rewarding the reporter in the amount \( \phi(c_i) \) if state of the world \( i \) occurs. Assume that \( \phi(c_i) > 0 \) if \( c_i > 0 \), and that \( \phi(\cdot) \) is strictly increasing and strictly concave; that is, assume that the source can reward the reporter at a cost to the source, and that the source can always increase the reward to the reporter by incurring more cost but that there are diminishing returns to this reward/transfer activity. Also assume that the source seeks to influence the reporter to choose action \( 1 \) with a set of rewards that minimize the source’s cost. Thus, the source wants to identify \( c_i^* \), where \( i = 1, 2, \ldots, n \), that solve the following constrained maximization problem:

\[
\text{(18)} \quad \max_{c_1, \ldots, c_n} \sum_{i=1}^{n} p_{ii} (u_i - c_i)
\]

subject to

\[
\sum_{i=1}^{n} p_{ii} (v_i + \phi(c_i)) \geq \sum_{i=1}^{n} p_{in} (v_i + \phi(c_i)).
\]

The Kuhn-Tucker first-order conditions for maximization problem (18) include

\[
\frac{1}{\phi'(c_i^*)} = \lambda^* \left[ \frac{1 - \frac{p_{in}}{p_{ii}}}{\lambda^*} \right], \quad i = 1, 2, \ldots, n,
\]

where \( \phi'(c_i^*) \) is the first derivative of \( \phi(\cdot) \) evaluated at the optimal cost for state \( i \), \( c_i^* \), and \( \lambda^* \) is the optimal value of a Lagrangian multiplier for the constraint. The assumptions that the reporter prefers action \( m \) (see statement (11)), and that \( \phi(\cdot) \) is strictly increasing, imply that the constraint will be binding and hence that \( \lambda^* > 0 \). The regularity properties of \( \phi(\cdot) \) and the conditions of statement (19) imply that \( c_i^* \) varies inversely with \( p_{in}/p_{ii} \). Thus, if we consider two states, \( i = s \) and \( i = k \), then statement (19), strict positive monotonicity and strict concavity of \( \phi(\cdot) \), and \( \phi(c_i) > 0 \) for \( c_i > 0 \) give us the following result:
Statement (20) gives us the key insight needed to understand the conditions under which the source can implement an implicit contract that will induce the reporter to choose action 1 even though the source cannot observe the chosen action, as we will now explain.

An expression of the form \( \frac{p_{im}}{p_{il}} \) is known in the statistics literature as a likelihood ratio. It gives us the ratio of the likelihood of observing (outcomes from) state \( i \) given that the reporter chose action \( m \), to the likelihood of observing (outcomes from) state \( i \) given that the reporter chose action \( 1 \). If state \( i \) occurs, then a high value of \( \frac{p_{im}}{p_{il}} \) is evidence that favors the inference that the reporter chose action \( m \). Similarly, if state \( i \) occurs, then a low value of \( \frac{p_{im}}{p_{il}} \) provides support for the inference that the reporter chose action \( 1 \).

The appearance of the likelihood ratio in the necessary conditions of statement (19) suggests that the source’s ability to implement a system of rewards that will induce the reporter to choose the action favored by the source is formally related to problems of statistical inference. A common regularity condition that is used for such inference is known as the monotone likelihood ratio property (MLRP). In the present context, the MLRP implies that \( \frac{p_{il}}{p_{im}} \) is a monotone-increasing function of \( u_i \). This means that the higher the utility payoff to the source, the more likely it is that the reporter chose the action that is favorable to the source. If the MLRP is satisfied, then the source’s contracting problem is relatively simple. In order to induce the reporter to choose action \( 1 \), all the source needs to do is to make a credible promise to the reporter of a sufficiently
generous plan to share the payoffs in a monotone-increasing way by adopting a rule such as this: if \( u_k > u_s \), then \( c_k > c_s \) and \( \phi(c_k) > \phi(c_s) \).

The MLRP makes it possible for the source to offer the reporter an implicit contract that will induce the reporter to choose to write a less truthful story. Whether or not the source would choose to offer the reporter such a contract depends on how high the reporter's "price" (the \( c^*_i \)) is, the source's relative evaluations of the reporter's actions (\( m \) and \( l \)), and the source's utility from the best alternative to dealing with the reporter. Thus, analogously to statements (16) and (17), we now have the necessary conditions,

\[
(21) \quad \sum_{i=1}^{n} p_{ui} (u_i - c^*_i) > \sum_{i=1}^{n} p_{im} u_i
\]

and

\[
(22) \quad \sum_{i=1}^{n} p_{ui} (u_i - c^*_i) > \bar{u}.
\]

Condition (21) means that the source would be willing to incur an expected cost of

\[
\sum_{i=1}^{n} p_{ui} c^*_i
\]

or slightly higher, in order to induce the reporter to choose action \( l \) rather than action \( m \). Condition (22) means that the source would prefer to incur this expected cost rather than withhold information from the reporter and receive the utility payoff, \( \bar{u} \), from the best alternative to dealing with the reporter.

We have identified conditions under which it would be possible for a single source to induce a single reporter to choose to write a less truthful rather than a more truthful story. To the extent that these conditions are in fact satisfied, the existence of a bilateral monopoly (i.e., single source, single reporter) relationship in journalism will foster inaccuracy. Competition among multiple sources and/or multiple reporters would check this cause of inaccuracy. Thus the existence of multiple sources, with intersecting sets of insider information, would allow even a single
reporter to "play off" each source against others as the sources competed to put their preferred "spins" on the reported news. Furthermore, the existence of multiple reporters would make it difficult or impossible for even a single source to induce reporters to choose less truthful over more truthful reporting. The reason for this is that the reward (or punishment) actions that are available to a source operating within a free-press political environment are essentially limited to granting (or not granting) future access to insider information. Such a reward (or punishment) action only has significant value (or cost) to a reporter if the access (or lack of access) to the insider information is exclusive.

**DIMENSIONS AND DIRECTIONS FOR FUTURE ANALYSIS**

Obviously, a more comprehensive analysis of journalism in the spirit of this chapter must take many additional factors or variables into account. We briefly identify some of these factors in this final section.

The preceding section focused on news reports based on "insider" statements. Most news, however, is generated through channels that are open to other reporters, such as official proceedings (trials, election tabulations, and the like), press releases, press conferences, background briefings, and news reports from other news organizations (see Sigal 1973, ch. 6). Such news is available to all reporters, so every reporter (or newspaper) is in competition with the rest of the media in its handling of the story. No reporter can accommodate the source without considering how his or her own story may look to the public or the professionals when compared with competing stories on the same subject.

When multiple sources of information about an event exist, a reporter has two tasks or decisions to make. First, the reporter must discover such sources and what they have said, or actively invite them to comment on the topic in question. Second, in deciding what competing sources to quote in a story, a reporter must decide which of these sources are sufficiently credible to be included. Sources that are wholly noncredible to the readership will presumably be excluded, since their inclusion could impugn the newspaper's reputation. For example, in their handling of the Gulf of Tonkin incident, which precipitated American escalation in Vietnam, the American media simply reported the statements of President Johnson, who spoke of "renewed hostile actions against U.S. ships on the high seas in the Gulf of Tonkin" (quoted in Hallin 1986, p. 19). In fact, there was serious doubt among those involved in the (second) Gulf of Tonkin incident whether any "battle" actually took place, as Johnson
claimed. The sonarman on the U.S. ship the Maddox had limited experience; and although he thought he detected torpedo after torpedo fired at the ship, many of the crew thought afterwards that he was probably picking up the sound of the ship's own propellers. The Maddox had great difficulty finding any targets on its fire control radar. Several hours after the engagement the commander of the task force cabled to Pacific headquarters:

Review of action makes many reported contacts and torpedoes fired appear doubtful. . . . Freak weather effects and overeager sonarman may have accounted for many reports. No actual visual sightings by Maddox. Suggest complete evaluation before any further action. (Quoted in Hallin 1986, p. 17)

Although the media did not have access to this report at the time, they did have access to the denials by the North Vietnamese that the alleged firing on the Maddox (in the relevant, "second" incident) actually took place. These denials were reported in Le Monde, for example, but the American press obviously regarded the North Vietnamese as noncredible sources. Or at any rate they were unwilling to run the risk of appearing to give any credibility to the North Vietnamese, presumably because of the expected reaction either of the U.S. government or the U.S. public.

The use of multiple sources can help correct distorting or misleading statements by single sources. But accuracy depends, in the end, on the accuracy or reliability of the sources selected. As many researchers indicate (e.g., Entman 1989), reporters typically depend for national news on easily accessible, familiar elites: top officials in the White House and executive branch agencies, members of Congress and powerful congressional staffers, representatives of important interest groups, and some party spokespersons, think-tank experts, former government officials, elder statesmen and stateswomen still involved in politics. Unfortunately, most of these elites are tainted; what they say is heavily influenced by policies they want enacted or privileges they want maintained. Instead of relying on rival elites, reporters can "mediate" a given source's claims by interpolating their own statements, explanations, or interpretations. The problem with this approach is that the ethos of journalism requires "balance" and "objectivity," which means that reporters must not themselves appear to be partisan or biased for or against a given source (e.g., a government official). Departures from the accepted journalistic ethos can result in sanctions from one's professional peers (a loss in reputation), sanctions from the public, and/or sanctions from one's boss (the editor or media owner). Nonetheless, explanations
and interpretations of a source’s statements can go a long way toward helping the audience reach an accurate assessment of the truth of a source’s statements.

A vivid example was some television coverage of Richard Nixon’s March 1974 appearance before the National Association of Broadcasters, while he was beset by the Watergate investigations. Immediately following the news conference, CBS broadcast live roughly three and a half minutes of instant analysis by correspondents Roger Mudd and Bruce Morton, which focused exclusively on Watergate (though this subject occupied only six of the eighteen questions posed during the news conference) and analyzed the president’s appearance in strategic terms. Mudd explained Nixon’s purpose as "to be seen as many places before as favorable an audience as he can arrange" and "to clothe the presidency with as much higher responsibility as he can bring to it." A subsequent experimental study of students’ reactions showed that those exposed to the instant analysis were greatly influenced by it (see Paletz and Entman 1981, pp. 66-67). Can network correspondents always be so assertive, however? How often can they engage in factual contradiction, judgment, and speculation about a president’s remarks? As Paletz and Entman (1981, pp. 69 ff.) emphasize, this is only "economically" feasible (our expression) under special circumstances. When presidential status is high, for example, it may not be feasible. Only during the waning or weakened period of a presidency can correspondents risk the cost of criticisms or sanctions from various quarters for such "bold" interpretations or statements of their own.

This raises questions about the effectiveness of the ethos of "balance" or "objectivity" in helping to secure truth. Ironically, it may be that the very ethos of objectivity is subversive of its own goal: greater truthfulness. The ethos of objectivity may constrain and deter correspondents from engaging in precisely the kind of analysis and interpretation that audiences need in order to get at relevant truths. Perhaps a change in ethos that allowed a more muck-raking or adversarial posture toward official sources (or any sources) would actually encourage greater truthfulness (at least more true belief on the part of the audience) than the precepts of reportorial balance and objectivity.

This kind of possibility emerges in a different form in a discussion by Paletz and Entman of the presentational style of network correspondents and anchorpersons. Paletz and Entman (1981, p. 24) point out that correspondents are authoritative and factual, their demeanor unemotional, uninvolved, dispassionate. They do not reveal strong opinions about the events they cover and are hardly ever emotional on camera. This style
comports with the ethos of objectivity, and it enhances the credibility of
the information and opinions which compose the news. But, observe
Paletz and Entman, this presentational product disguises the process of
selecting, framing, reconstituting, and reconstructing reality that is
actually taking place. The appearance of knowledgeability and
impartiality, it may be argued, contributes to credulity as opposed to
skepticism on the part of the audience. And ultimately, such credulity
may hinder the formation of true belief on the part of that audience.

Two other topics for the economic analysis of the news may be
mentioned briefly in conclusion. First, an economic approach should
come to terms with earlier models of the news with an economic tenor.
Two such models are called by Cohen and Young (1981, p. 13) the "mass
manipulative model" and the "market or commercial model." In the
manipulative model, those in power use the media to mystify and
manipulate the public. The market model argues that there is variety and
diversity in information and opinions presented in the mass media and
that such variation minimizes the chances of manipulation. Our
discussion does not mean to come down squarely on either side of this
dispute, but the elements of truth in each contender should be assessed.

Second, there is an element in the market model that is widely
endorsed, and we should give it at least passing attention before
concluding. This element concerns the nature of the public "demand" for
truth. Although we have defended the proposition that truth acquisition
is a "major" goal of readers, we certainly concede that truth is not their
exclusive interest. One way of putting the point is to say that the public
wants some but not all kinds of truths. Readers are more interested in
dramatic and simple truths, not abstract, dry, or complex truths. A
slightly different way of putting the point is not in terms of the truths
themselves, but the modes of presentation of truths. Audiences for news
are said to prefer the dramatic to the drab, the personalized to the
impersonalized, the simple to the complex, the unambiguous to the
ambiguous, and so forth. This demand shapes what newsmakers consider
newsworthy, and hence what ultimately appears on television or is given
prominent coverage in the print media. The question is how much this
distorts the body of information (or misinformation) available to the
citizenry. It is easy to say, of course, that the result is very poor
"quality" of information. But it would be good to have a more precise
analysis of how audience preferences for certain modes of presentation,
and putative dispositions to minimize cognitive effort in assimilating
news, result in actual falsity or inaccuracy of belief.
Notes

1. The model developed in this section adapts a type of analysis originated by Akerlof (1970) and Spence (1974).

2. The key role of the MLRP in some models of information asymmetry was previously demonstrated by Milgrom (1981).

3. Helpful comments and suggestions were provided by participants in the Social Science and Philosophy Workshop at the University of Arizona. Cox’s work on this chapter was partially supported by the National Science Foundation (grant number SES-9108888).