The Value of Information in Efficient Risk-Sharing Arrangements

By EDWARD E. SCHLEE*

Suppose that agents share risks in competitive markets. We show that better information makes everyone worse off if the economy has a representative agent—that is, the economy's demand for state-contingent consumption equals the demand of a hypothetical agent who owns all the economy's wealth. The representative agent, moreover, is normatively unrepresentative: although each agent dislikes information, the "representative" agent is indifferent. Although we emphasize pure exchange, our results imply that a representative-agent model might seriously misstate the welfare effects of improved information in an economy with production and risk sharing, even if it performs well otherwise. (*JEL* D8)

Suppose that advances in genetic testing allow us to predict more accurately whether an individual will contract a particular disease. Will individuals be better off as a result? If the information is public they might not be, since the information will change the terms of insurance against that illness: If, *on average,* the price of insurance with better information is high enough, then an individual might be worse off *ex ante* with better information about his health.

Indeed, recent studies confirm that individuals often refuse free genetic-testing results. Caryn Lerman et al. (1996) report that 57 percent of a group of subjects with a family history of breast/ovarian cancer declined to receive free test results for mutations of the BRCA1 gene—a potent predictor of hereditary breast and ovarian cancer.[1] Among the reasons listed against being tested, the most frequent "very important" reason was fear of insurance consequences should the results somehow become public. Similarly, Kimberly A. Quaid and Michael Morris (1993) find that fear of losing insurance helps explain the high rate of declining free genetic testing for Huntington's disease (among individuals who have a close relative who is a carrier). Rejection of costless information is, of course, difficult to explain with conventional single-agent decision theory, but is much easier to understand if the information is potentially public.

That public information might make agents worse off *ex ante* was noted long ago by Jack Hirshleifer (1971) in the context of an exchange economy for risk. In his example (p. 568), there

* Department of Economics, Arizona State University, Tempe, AZ 85287 (e-mail: ed.schlee@asu.edu). I thank Dirk Bergemann, Michele Boldrin, Hector Chade, Manjira Datta, Keith Crocker, Christian Gollier, John Hey, Richard Kihlstrom, Alejandro Manelli, Mike Ormiston, Kevin Reffett, Peter Sørensen, three referees, and seminar/conference participants at Arizona State University, the University of Arizona, the University of California-Davis, Michigan State University, the University of Michigan, Stanford University, Tulane University, the FUR IX conference in Marrakech, the 25th Seminar of the European Group of Risk and Insurance Economists in Geneva, and the 1999 Fall Midwest Economic Theory conference at the University of Illinois, Urbana-Champaign for comments or (sometimes lively) discussions relating to the ideas in this paper. The Arizona State University College of Business provided a grant which partially funded this research. I did part of this work while visiting the University of Michigan Economics Department during the Fall of 1999, and I thank that department for its hospitality.

[1] The participants were 279 adults who were members of families with hereditary breast or ovarian cancer. They were initially contacted by mail and given the chance to participate in a baseline telephone interview. Of the original set of participants, 192 agreed to do so, and 40 percent of these declined to receive BRCA1 test results. All the participants, however, were given the option of simply receiving their test results free of charge. Of the original 279, only 43 percent requested their results (i.e., six of those who refused the baseline interview chose to receive their test results). It should be emphasized that the decision to accept or turn down test results were real decisions, not simply survey responses.

are two states of the world, agents are risk averse, and the endowments of wealth in the two states differ across the agents. If the agents trade in complete markets for contingent claims before the state is realized, then they will share some of the risk. If, however, the agents perfectly learn the state before they trade, then there will be no trade at all; thus, from an *ex ante* viewpoint, under perfect information each agent simply consumes his endowment, which is Pareto inferior to the allocation of risk with no information.

Several papers have generalized aspects of Hirshleifer's example. John M. Marshall (1974 Section IB) noted that, from a position of no information, partial information cannot be a Pareto improvement if markets are complete and prior beliefs common: if some agent benefits *ex ante* from the information, some other agent must be hurt. Jerry R. Green (1981 Section 4 Theorem) and Nils H. Hakansson et al. (1982 Lemma 3) each gave versions of this result using very general definitions of "better information."[2] More recently, Eyal Sulganik and Itzhak Zilcha (1996) showed that the value of information about exchange rates could be negative for an exporting firm in the presence of futures markets for currency. Finally, Jonathan B. Berk and Harald Uhlig (1993) present conditions for a class of dynamic exchange economies ensuring that a positive measure of agents *prefer* more information.[3]

Excepting the last paper, these extensions of Hirshleifer's example all show that a *particular* informational improvement (partial information starting from no information) may make *some* agents worse off in a competitive equilibrium allocation of risk. The only paper that we know of to generalize the unanimity aspect of Hirshleifer's example is Robert Wilson (1975), who showed that better information is Pareto inferior if agents all have log utility functions, but different endowments. Our main purpose is to find general conditions implying that all agents are made worse off by any improvement in public information.[4]

Our main result (Theorem 2) is that, if all agents are weakly risk averse, then better public information is Pareto inferior in a competitive equilibrium risk allocation under any *one* of the following three assumptions: there is no risk in the aggregate; some agents are risk neutral; or if the economy has a (positive) *representative agent.* The second case describes competitive insurance markets, with the risk-neutral agents as insurers. The third finding is the most surprising. By an economy having a representative agent, we mean that the economy's aggregate demand for state-contingent consumption equals the demand function of a hypothetical agent who owns all the economy's resources. In particular, aggregate demand simply depends on aggregate wealth, not its distribution, and it satisfies all the properties that individual demand functions satisfy.[5] W. M. Gorman (1953) showed in his classic paper that a representative agent exists if, for each commodity, the Engel curves of consumers (at fixed prices) are straight lines with common slope. This condition permits essentially arbitrary distributions of wealth and also some heterogeneity in preferences. (To give two simple examples, this condition is met if consumers all have preferences that are quasi-linear with respect to the same good; or if they have the *same* homothetic preferences—e.g., constant elasticity of substitution [CES] utility.) The significance of our result depends critically on having a representative agent in a heterogeneous economy. If agents are identical—the same preferences *and* endowments—then risk-sharing markets would not be active at all: each agent simply consumes

[2] Green's (1981) emphasis is on the value of public information in a partial-equilibrium framework in the presence of futures or options markets. Hakansson et al. (1982) showed that better public information can be Pareto *superior* if endowments are an equilibrium and either that the equilibrium is inefficient for some reason or that prior beliefs are not common.

[3] We defer discussion of this work until the end of Section III.

[4] Keith J. Crocker and Arthur Snow (1992) and Neil A. Doherty and Paul D. Thistle (1996) examine the value of *private* information in an insurance setting. The former also shows that public information is socially valuable in a linear signaling model when agents are risk neutral and have prior private information.

[5] Chapter 4 of Andreu Mas-Colell et al. (1995) is an excellent introduction to aggregation and representative agents. Angus Deaton and John Muellbauer (1980 Chapter 6) is also very useful.

his endowment and thus is always indifferent about information. In order for information to be *strictly* inferior, agents must differ so that risk-sharing markets are active.

We think that our main finding is interesting for at least two reasons. First, applications of risk-sharing models often impose assumptions, wittingly or not, that ensure the existence of a representative agent. Second, a representative agent in an exchange economy is always indifferent about information, since that "agent" always consumes the entire endowment. Yet our theorem shows that each agent in the economy is (at least weakly) worse off: the "representative" agent is thus *Pareto inconsistent* in the sense that its preferences for information disagree with the unanimous preferences of the agents.[6]

Several papers have shown that representative agents can be Pareto inconsistent for evaluating different price vectors under certainty (Michael Jerison, 1984, 1996; James Dow and Sérgio Ribeiro da Costa Werlang, 1988; Alan P. Kirman, 1992). In this literature, however, an economy satisfying Gorman's Engel-curve restriction will necessarily have a Pareto-consistent representative agent: in that case, if all agents agree that price vector **A** is better than **B**, then so will the representative agent. Thus, these papers must look elsewhere for a Pareto-inconsistent representative agent. By contrast, our theorem implies that the mere existence of a positive representative agent is enough to ensure that it is Pareto inconsistent for information valuation (assuming that risk-sharing markets are active to begin with). Thus a representative-agent model is *especially* suspect for evaluating information: either it is a bad positive model; or it is a good positive model, in which case our theorem implies it is a bad normative model for valuing information.[7]

The reason why the value of public information might be negative for an agent in a market or game is that such information affects not only that agent's action, but also the actions of other agents: the latter effect might be bad enough to outweigh the direct benefit of information on a agent's action. This possibility is especially easy to understand if the equilibrium is inefficient, as Nash equilibria of games often are: with less information, players might achieve Pareto-superior payoffs in some states of the world. Leonard J. Mirman et al. (1994) use this argument to explain why the value of information about demand is sometimes negative for Cournot duopolists: by not knowing demand, the firms might get closer to the collusive outcome in some states.[8] More generally, if the Nash equilibrium is inefficient, then not knowing the game may serve as a commitment device to ensure cooperation in some states.[9] Hence *one* reason that the value of public information is sometimes negative in a game is the inefficiency of Nash equilibria. We will focus on Pareto-efficient solutions to risk-sharing problems, thus removing inefficiency as a source of a negative value of information.

The result that the value of public information is negative has several implications. In insurance markets it may mean that better underwriting—a more precise assignment of individuals to risk classes—may make both insurers and insurees worse off. As Michael Rothschild and Joseph E. Stiglitz (1997) observe, this possibility might lead to excessive underwriting in equilibrium: each insurance

[6] Thus if we try to use the preferences of the representative agent as social preferences, they will violate Kenneth Arrow's basic unanimity condition in social choice: if everyone prefers A to B, then the social ordering should rank A above B.

[7] Of course, our theorem has no bearing on the positive validity of representative-agent models, nor does it imply that they are necessarily invalid for other policy questions. It does reinforce, however, the message from the extant literature on unrepresentative representative agents: its relevance for welfare comparisons cannot be deduced from positive validity.

[8] Joseph E. Harrington, Jr. (1995) also finds the value of information about demand is sometimes negative for firms selling differentiated products.

[9] A simple prisoner's dilemma illustrates this point clearly. Let each player receive a payoff of 2 if they both cooperate and 0 if they both defect; if one defects and the other cooperates let the former get 3 and the latter get a payoff of -1. If they know the game they are playing they each get 0 in equilibrium, the only inefficient outcome. Suppose, however, that the players don't know which of their actions leads to cooperation: each has two actions, A and B; with probability ½ the cooperative action is A, and with probability ½ it is B. In this game of incomplete information (keeping the payoffs to combinations of cooperation and defection the same), any choice leads to an expected payoff of 1, which Pareto-dominates the equilibrium outcome if the game is known. Intuitively, in the incomplete-information game they cooperate half the time if they both choose A or both choose B.

company might find it profitable to improve underwriting, but if the result is better public information about the probability of losses, then all market participants might be worse off.

Although insurance is the most obvious application of our results, risk-sharing models are also used in other areas of economics, including macroeconomics, labor economics, and development economics. Thus our findings are potentially relevant to these areas as well. In macroeconomic models, for example, agents are uncertain about shocks that generate business cycles. One way to improve information is to develop better models of business cycles. If agents share risks, however, better forecasting of such shocks might make agents worse off. Of course, these applications typically involve production, not just exchange, and we emphasize the latter. Nevertheless our results suggest that a representative-agent model might seriously misstate the social value of learning about business cycles.[10]

The paper is organized as follows. Section I sets out the notation. Section II gives some preliminary results that help set the previous findings in context. We present our main results on the value of information in competitive risk-sharing markets in Section III. Section IV then presents some applications; since these most naturally involve production, we begin that section by briefly discussing how production affects our results: in a production economy with a representative agent, information can be either good or bad for agents; but even if it is good, the representative agent will not generally measure its benefits well. Section V concludes the paper.

I. The Model

We consider an exchange economy with n agents, S states of the world and a single physical consumption good.[11] Agent i is endowed with $\omega(s, i)$ units of the good in state s; let $\omega(s) = \sum_{i=1}^{n} \omega(s, i)$, the aggregate endowment of the good in state s. Each agent i has a differentiable, concave, and strictly increasing von Neumann-Morgenstern utility u_i on $\mathbb{R}_+$, and agents have a common prior belief $\boldsymbol{\pi}$ over the states. An allocation is a feasible assignment of a nonnegative consumption level to each agent in each state: $\omega(s) \geq \sum_{i=1}^{n} c(s, i)$ for all s. Before an allocation is chosen, agents may observe a signal z from a set Z that reveals information about the state. Observing the random variable z reveals information if it is correlated with the state: loosely, the higher the correlation, the more informative the observation. Formally, fixing the set Z, an *information structure* is a vector $\mathbf{q} = (q_1, \ldots, q_S)$ of probability distributions over Z: q_S gives a probability distribution over Z conditional on s being the state. The (unconditional) probability of observing z is $\lambda(z, \mathbf{q}) = \sum_{\sigma=1}^{S} \pi(\sigma) q_\sigma(z)$, where $q_\sigma(z)$ is the probability of seeing signal realization z given that the state is σ. After observing z, agents update beliefs about the state; the posterior belief that the state is s after observing z is $p(s|z; \mathbf{q}) = \pi(s) q_S(z)/\lambda(z, \mathbf{q})$. An information structure is *null* (uninformative) if all the coordinates of $\mathbf{q}$ are the same, in which case the posterior belief will equal the prior belief for every z; it is *perfect* if the posterior belief $p(s|z; \mathbf{q})$ is either zero or one for all states and signal realizations. An *allocation rule* gives an allocation of state contingent consumption for every signal realization z from any information structure $\mathbf{q}$. An allocation rule is *efficient* if it gives a Pareto-efficient allocation for every $\mathbf{q}$ and z: for each z, there is no other allocation that raises the expected utility of one agent without lowering the expected utility of another agent, where the expected utilities are calculated using the posterior beliefs $p(\cdot|z; \mathbf{q})$.

An important example of an efficient allocation rule is a competitive equilibrium: for each z and $\mathbf{q}$, the allocation is a competitive equilibrium resulting from the endowments and posterior belief $p(\cdot|z; \mathbf{q})$ about the state. Alternatively, the allocation could be the outcome of a cooperative bargaining game that imposes efficiency, such as the Nash bargaining solution; or the outcome of maximizing a weighted social welfare function; or a simple sharing rule, such as "each agent gets a fixed fraction of the

[10] The value of information about business cycles is closely related to Robert E. Lucas, Jr.'s (1987) question of the welfare cost of business cycles, which we briefly discuss in Section IV. Marshall (1974), Marcel Boyer et al. (1989), and Bernard Eckwert and Zilcha (1999) look at the value of information in a production economy, the last two in a dynamic setting.

[11] The single-good assumption is largely for convenience. One may readily verify that our main result, Theorem 2 (iii), goes through in the multiple commodity case.

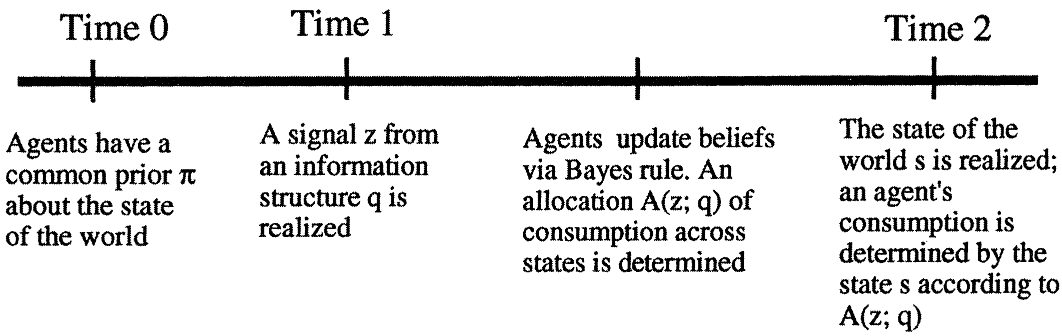

FIGURE 1. TIMING

amount of the good available in each state."[12] For each of these rules, the signal affects the allocation only through beliefs: any two signal realizations that give the same beliefs result in the same allocation. This restriction is natural, since the purpose of gathering information is to affect beliefs, and two pieces of news that lead to the same beliefs have the same informational content. Accordingly, we will assume henceforth that the allocation rule depends directly on beliefs and write $A(p(\cdot|z; \mathbf{q}))$ for the allocation that results from observing z from $\mathbf{q}$.

Figure 1 illustrates the sequence of events we have in mind. Agents start off at time 0 with a common prior belief $\boldsymbol{\pi}$. At time 1 a signal z from an information structure $\mathbf{q}$ is realized; all agents see z and know the information structure $\mathbf{q}$ from which it is drawn. Agents then update beliefs and an allocation of consumption across states is chosen according to the allocation rule $A(\cdot)$ and the realization z from $\mathbf{q}$. Finally, at time 2 the state is revealed and agents consume according to the allocation. The comparative statics question we ask is the following: from an *ex ante* (time 0) perspective, what is the effect on the welfare of agents of an improvement in the information structure at time 1, given an efficient allocation rule $A(\cdot)$?[13]

The definition of "better information" that we use is the standard definition of David Blackwell (1953) using the statistical notion of sufficiency. Although the main idea of the paper can be grasped without it, we have gathered together the standard definitions and some useful facts about information structures in Appendix A.

II. Information in Efficient Risk-Sharing Arrangements

Our first result helps fix the limits of what better information can achieve in the context of efficient risk-sharing rules; it also provides a transparent explanation for the finding that better information cannot be Pareto superior in a competitive allocation of risk, and indeed extends that finding to *all* efficient risk-allocation rules. Consider the *ex ante* (time 0) utility possibilities set for an information structure $\mathbf{q}$: the set of expected utilities that are obtainable for an information structure by varying allocations made at time 1. Theorem 1 shows that the *ex ante* utility possibility set is invariant to the information structure. (All proofs are in Appendix B.)

THEOREM 1: *If all agents are risk averse, then the ex ante (time 0) utility possibilities set is the same for all information structures* $\mathbf{q}$.

Since the allocation from no information is *ex ante* efficient we immediately get the following corollary, which extends to all efficient

[12] This rule is efficient for some preference specifications.

[13] Note that, although markets are complete after the news is learned, we do not allow agents to insure against news. This is the standard way to pose the question of information value in decision theory and game theory. Of course, if more information is Pareto inferior, then there will be incentives either to insure against its effects, or prevent the information from being used. One way to interpret our results is to determine when such incentives exist. Green (1981 Section 4) clearly explains the importance of timing of trades and information; our analysis is subsumed under his case "C" in his Section 4.

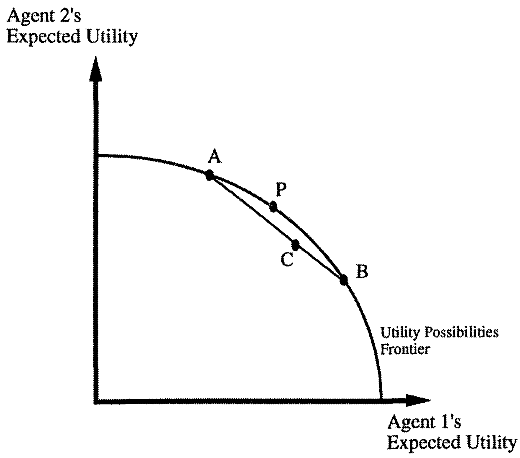

FIGURE 2. UTILITY POSSIBILITIES SET

Notes:
P = expected utilities with no information.
A = expected utilities after z_1 is realized.
B = expected utilities after z_2 is realized.
C = *ex ante* expected utilities with information.

risk-allocation rules Marshall's (1974)[14] finding that, starting from null information, better information cannot be a Pareto improvement in a competitive equilibrium allocation of risk.

COROLLARY TO THEOREM 1: *Let $A(\cdot)$ be an efficient allocation rule that depends merely on the probability distribution over states and suppose the economy starts with null information. Then better information cannot lead to a Pareto improvement: if any agent is better off with information, some other agent must be hurt by it.*

Figure 2 gives the intuition for the corollary for the case of two agents using the (expected) utility possibility set. By risk aversion, this set is convex. For simplicity, we consider the case of no aggregate risk; hence the set is the same for every *posterior belief.* Point P indicates a possible expected utility vector for a null information structure. Suppose now that the economy has access to an information structure with two possible signal realizations which yield the expected utility vectors A and B in the figure. If either A or B differs from P, then the *ex ante* expected utility from information—e.g., vector C—will be off the frontier and hence at least one agent will be worse off with improved information. Without pinning down the allocation rule, however, we cannot say that *all* agents are worse off. Moreover, as Green (1981) points out, it could happen that, starting from *partial* information, better information could be a Pareto improvement. In Figure 2, if the partial information vector of expected utilities is off the frontier from the time 0 perspective, better information might move that vector toward the frontier in a way that makes everybody better off.

An example of an allocation rule that leaves agents indifferent about better information is the allocation from maximizing a weighted utilitarian welfare function (for fixed weights), that is picking the allocation to maximize

$$\sum_{i=1}^{n} \alpha_i \left[\sum_{s=1}^{S} u_i(c(s, i))p(s) \right], \tag{1}$$

subject to the resource constraints, where the α_i's are all positive and sum to one. In that case the allocation is independent of probabilities and hence information, so the *ex ante* expected utility vector remains on the frontier. For special forms of the utility function[15] these allocations give each agent a linear function of the total amount of the good in each state. Robert M. Townsend (1993 Chapter 2) applied this result in his analysis of the medieval village economy. Specifically, he considered whether it was possible for *ex ante* division of land in a village to yield an *ex ante* efficient allocation of consumption (with each household simply consuming the food on its plot). An interesting implication of using program (1) to solve a risk-sharing problem is that the value of information is precisely zero for every agent.[16]

[14] And its statements in Green (1981) and Hakansson et al. (1982).

[15] For example, if all agents have constant absolute risk-aversion utility; or if all agents have identical constant relative risk-aversion utility.

[16] Although every competitive equilibrium allocation can be achieved as a solution to (1) for some choice of weights, it does not follow that the value of information will be zero for every agent in a competitive equilibrium: as the

III. Better Information in Competitive Risk-Sharing Markets

Henceforth we consider the competitive allocation rule: for each belief p the allocation is a competitive equilibrium given p and the endowments. The following theorem gives three conditions under which better information makes each agent worse off. The most surprising of these is simply that the economy has a (positive) representative agent who satisfies the expected utility hypothesis. By a *representative agent* we mean that the economy's aggregate demand equals the demand function of a hypothetical agent who owns all the economy's resources: specifically, there exists a von Neumann-Morgenstern utility such that the corresponding demand function for an agent who owns the economy's endowment equals the aggregate demand of the actual economy.

THEOREM 2: *Consider the competitive equilibrium allocation. Better information is Pareto inferior*[17] *under any one of the following conditions: (i) all agents are risk averse and there is no aggregate risk; (ii) some agents are risk neutral and others are risk averse (and the risk-neutral agents own enough to insure the risk-averse agents fully); (iii) all agents are risk averse and the economy has a representative agent who satisfies the expected utility hypothesis with a concave, differentiable von Neumann-Morgenstern utility function.*

Theorem 2(i) covers the oft-analyzed case of no aggregate uncertainty; (ii) covers the case of competitive insurance markets (in the absence of transactions cost): the risk-neutral agents are insurers and risk-averse agents are insurees;[18] (iii) is at first surprising, since, with a representative agent, the problem "looks" like a single-agent problem. Yet, even though an isolated agent never dislikes more information, Theorem 2 (iii) asserts that *all* agents in such an economy at least weakly dislike any increase in information. Recall that we need the qualifier "at least weakly" for the case in which risk-sharing markets are not active—e.g., agents have the same preferences *and* endowments. In that case, each agent is indifferent about information, since each simply consumes his endowment. Of course, in that event there is no risk sharing at all. In order for (iii) to have bite there needs to be some heterogeneity in economy so that risk-sharing markets are active.

The intuition for parts (i) and (ii) of Theorem 2 is clear. In each case, risk-averse agents fully insure if there is no information, consuming the expected value of their endowments. With information they will continue to insure fully for each signal realization, but, since the signal is random, information introduces risk from an *ex ante* perspective, leaving them worse off; and, the more precise the information, the greater the *ex ante* risk.

How is it that the existence of a representative agent implies a negative value of information? The reasoning here is more complex, but we can convey the idea in the two-state, two-agent case with an Edgeworth box diagram (Figure 3). Let e denote the endowment, and suppose we compare no information to an information structure with two possible signal realizations. Let the realizations give rise to two distinct price vectors, and let the corresponding allocations be given by points A and B in Figure 3. The argument has two steps: first we construct an artificial allocation that is less risky than the equilibrium random consumption with information, an allocation that all agents prefer since they are risk averse; we then show that the equilibrium allocation with no information is *revealed preferred* to that artificial allocation. To begin, note that when evaluating the partially informative structure from an *ex ante* viewpoint, each agent faces a random consumption that may take on four possible values, two for each of the two states. We now construct a new allocation by replacing each agent's random consumption in each state with its expected value, using the probability of allocations A and

probabilities change in response to news, the weights in (1) would have to change to support the competitive equilibrium, so agents would not necessarily be indifferent.

[17] By Pareto inferior here we mean that no agent is better off; generally, however, some agent will be strictly worse off. What is needed for an agent to be worse off is that information should change that agent's consumption.

[18] Theorem 2(ii) is related to Proposition 1 of Boyer et al. (1989). The latter considers an individual in a two-period insurance model with fair pricing. They find that the use of experience rating to set second-period premiums makes the individual worse off *ex ante;* such rating amounts to conditioning on better information.

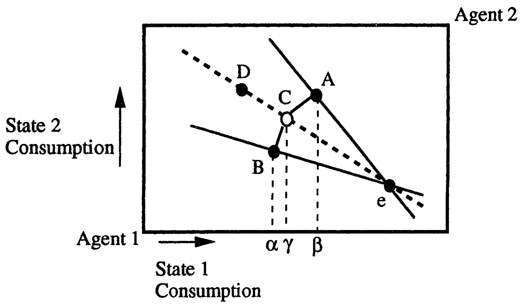

FIGURE 3. WHY THE VALUE OF INFORMATION IS NEGATIVE IN AN ECONOMY WITH A REPRESENTATIVE AGENT

Notes:
e = endowment.
A, B = allocations after signal is revealed.
C = "averaged" allocation, less risky than the *ex ante* random allocation (A, B) with information.
D = allocation with no information, which is Pareto superior to C by revealed preference.

B *conditional* on that state.[19] For example, in Figure 3 we replace agent 1's random state-1 consumption that yields either α or β with its (state-1-conditional) mean, γ. Doing this for each state and agent will yield a new allocation, C in Figure 3. Each agent will prefer this new random consumption to the lottery between A and B since the former is a mean preserving *decrease* in risk with respect to the latter (Rothschild and Stiglitz, 1970). Now we bring the representative-agent assumption to bear. That assumption constrains the relationship between equilibrium prices and probabilities: in particular, relative state prices are always proportional to the relative state probabilities (since equilibrium relative prices equal the representative agent's marginal rate of substitution [MRS] at the aggregate endowment, and the MRS for expected utility is proportional to the probabilities).[20] This fact, in turn, implies that the equilibrium price vector without information will equal the *mean* of the random prices with information, since the mean of posterior beliefs must always equal the prior belief.[21] A little algebra then reveals that the allocation C lies *on* the equilibrium budget line in the economy with no information (represented by the dashed line in Figure 3). Hence, the equilibrium allocation without information (say D) is *revealed preferred* by all to allocation C, which in turn is preferred by all to the random consumption with information. In sum, better information leads to a new allocation that is *ex ante* riskier than one that is *revealed worse than* the original allocation.

One virtue of Theorem 2 (iii) is that it doesn't depend on how the representative-agent condition is justified; its generality, of course, might also be considered a vice, since it is not specified in terms of the primitives of the problem, preferences, and endowments. As we noted in the introduction, a sufficient condition for a representative agent is that, for each good, the Engel curves of consumers are straight lines with common slope (Gorman, 1953).[22] Of course, in our application, the "goods" are state-contingent consumption of the single physical good; moreover, we restrict preferences over such commodity bundles to satisfy expected

[19] If **q** represents the information structure, then we use the probability distribution $q_S(z)$ for state s.

[20] If U is the von Neumann-Morgenstern utility for the representative agent, then equilibrium prices **r** must satisfy $r_S/r_\sigma = p_S U'(\omega(s))/p_\sigma U'(\omega(\sigma))$ for every pair of states s and σ; this implies that the representative agent will demand the aggregate endowment, so supply will equal demand.

[21] Normalize prices so that $r_S = p_S U'(\omega(s))$ from footnote 20. This formula must hold for the prior belief and for each possible posterior belief. Since the expected posterior must equal the prior belief, the expected price vector with information will equal the equilibrium price vector with no information. And since better information makes the posterior beliefs riskier (see Appendix A), it also makes the equilibrium prices riskier.

[22] This condition ensures among other things that aggregate demand depends on aggregate income and not how it is distributed. There are other sufficient conditions for a representative agent, but we also require the representative agent to satisfy the expected utility hypothesis: just because all the agents in the economy are expected utility maximizers doesn't mean that a representative agent, if it exists, will be as well. For example, suppose that agents have *distinct* constant relative risk-aversion utility ($u(c) = (1/\alpha)c^\alpha$) and that endowments are proportional to the aggregate endowment. Then there is a representative agent (E. Eisenberg, 1961); in particular this agent's preferences are representable by a utility function that is the maximum of the product of the homogeneous of degree-1 version of each agent's utility function over contingent consumption (where the product is maximized over each agent's consumption of each good, subject to the constraint that the sum of consumption equals aggregate consumption). These preferences, however, will not generally satisfy the expected utility hypothesis.

utility. The following proposition, found in M. J. Brennan and Alan Krauss (1978), simply specializes Gorman's condition to our setting. The condition is simplest to write using the measure of *risk tolerance*, $T_i(c) = -u_i'(c)/u_i''(c)$, which is the inverse of the usual Arrow-Pratt risk-aversion measure. The required condition is that risk-tolerance functions of consumers are all straight lines with common slope.

PROPOSITION: *Suppose that the risk-tolerance functions of all consumers are straight lines with common slope; that is, each consumer i's risk-tolerance function is of the form* $T_i(c) = \alpha_i + \beta c$ *for constants* α_i *and* β, *where* β *is common across consumers. Then the Engel curves for consumption in each state are straight lines with common slope across consumers, and the economy has a representative agent.*

The following corollary gives classes of preferences satisfying the conditions in the proposition; direct calculation shows that the representative agent in each case satisfies the expected utility hypothesis.

COROLLARY TO THE PROPOSITION: *The economy has a representative agent satisfying the expected-utility hypothesis if all agents have a utility function in exactly one of the following four classes: (i) quadratic utility (i.e., household i's utility is* $u_i(c) = \alpha_i c - \beta_i c^2$, α_i, $\beta_i > 0$); *(ii) constant absolute risk-aversion utility* ($u_i(c) = -e^{-\lambda_i c}$, $\lambda_i > 0$); *(iii) the class* $u_i(c) = (1/\gamma)(c - \rho_i)^\gamma$, $0 \neq \gamma < 1$, *for all i, including identical constant relative risk-aversion utility; or (iv) Stone-Geary utility* ($u_i(c) = \ln(c - \rho_i)$).

The conditions of the proposition and its corollary are stringent. Nevertheless, these preference specifications cover the functional forms most often used in applied work involving uncertainty. Moreover, the condition places essentially no restrictions on the distribution of endowments[23] and permits agents to have different attitudes towards risk, although the form of preference heterogeneity allowed is constrained: agents must all have utility functions in exactly one of the four classes in the corollary, but are permitted to have arbitrary functions within the class.

A. *The Unrepresentative Representative Agent*

A very simple but important corollary of Theorem 2(iii) follows from observing that the representative agent is always indifferent about information. This agent always consumes the aggregate endowment no matter what the signal. Information thus never affects the representative agent's action and hence is valueless. Yet, each agent in the economy is worse off with better information: the positive representative agent is thus *normatively un*representative. As we have noted, Jerison (1984, 1996) and Dow and da Costa Werlang (1988) have examples of unrepresentative representative agents in evaluating different price vectors and aggregate income levels under certainty. One difference between these examples and our Theorem 2 (iii) is that the mere existence of the representative agent in our setting is enough to insure that it is unrepresentative for evaluating information. A Gorman representative agent, however, is necessarily Pareto consistent when comparing different price vectors and aggregate incomes.[24] An important implication of Theorem 2(iii) is that Gorman aggregation does not justify treating the positive representative agent as a normative representative agent for *all* policy questions, particularly those involving information. Why is it, then, that evaluating information leads to such a different analysis than evaluating prices under certainty? One peculiarity about information is that its arrival, by changing beliefs, changes consumer *preferences* over commodity bundles (which here are just state-contingent consumption plans). When prices change under certainty,

[23] In particular, consumers need enough wealth to avoid zero consumption in any state: if the Engel curves are straight lines that don't pass through the origin, then some must eventually crash into the nonnegativity constraint on consumption at low wealth levels (and hence become nonlinear).

[24] To obtain an unrepresentative representative agent, Jerison (1996) and Dow and da Costa Werlang (1988) cannot therefore appeal to Gorman aggregation. Indeed, they cannot appeal to Paul A. Samuelson's (1956) construct of a social planner who reallocates income to maximize social welfare, which also leads to a Pareto-consistent representative agent. See Mas-Colell et al. (1995 Chapter 4) for further discussion.

however, consumer preferences over commodities remain fixed by hypothesis.

Of course, if all agents in the economy are identical, then, as already noted, they are always indifferent about more information, and hence will agree with the representative agent. Presumably, however, a representative-agent model is interesting because it tells us something about actual economies with heterogeneous agents that actively share risk. In such an environment, our results imply that if the representative agent is a good positive model, then it must be a bad normative model for questions of information.

B. *Two Examples and Discussion*

To illustrate Theorem 2(iii), we now work out an example in which all agents have identical, constant relative risk-aversion preferences; as long as endowments are not proportional to the aggregate endowment, all agents will dislike information.

Example 1: Let each agent's expected utility be given by $(1/\alpha)\ \Sigma_{\sigma=1}^{S} p_\sigma(c(\sigma, i))^\alpha$, where $0 \neq \alpha < 1$ and let $\omega(s, i)$ be household i's endowment of consumption in state s for $i = 1, \dots, N$. Let $\mathbf{r} = (r_1, \dots, r_S)$ be the vector of prices for state-contingent consumption. Each household i takes prices as given and chooses a state-contingent consumption plan $(c(1, i), \dots, c(S, i))$ to maximize expected utility subject to its wealth constraint. Household i's first-order conditions are $r_\sigma/r_S = (p_\sigma/p_S)(c(s, i)/c(\sigma, i))^{1-\alpha}$ for every pair of states and $\Sigma_{\sigma=1}^{S} r_\sigma c(\sigma, i) = \Sigma_{\sigma=1}^{S} r_\sigma \omega(\sigma, i)$. Since this economy has a representative agent (with the same utility function as each of the agents), equilibrium prices are $r_\sigma/r_S = (p_\sigma/p_S)(\omega(s)/\omega(\sigma))^{1-\alpha}$ where $\omega(s)$ is the total endowment in state s. Thus in equilibrium each household's consumption is proportional to the aggregate endowment vector: $c^*(s, i; p) = B(i, p)\omega(s)$ for some number $B(i, p)$ that is independent of the state. Using the budget constraint we find that

$$B(i, p) = \frac{\sum_{\sigma=1}^{S} p_\sigma \omega(\sigma, i)(\omega(\sigma))^{\alpha-1}}{\sum_{\sigma=1}^{S} p_\sigma(\omega(\sigma))^\alpha}.$$

Thus, household i's value function from the competitive equilibrium when the belief is p is

$$V_i(p) = \alpha^{-1}\left(\sum_{\sigma=1}^{S} p_\sigma \omega(\sigma, i)(\omega(\sigma))^{\alpha-1}\right)^\alpha \times \left(\sum_{\sigma=1}^{S} p_\sigma(\omega(\sigma))^\alpha\right)^{1-\alpha}.$$

Standard arguments show that this function is concave in p; moreover it is nonlinear in p if agent i's endowment isn't proportional to the aggregate endowment.[25] Hence by the lemma in Appendix A, each agent dislikes better information. If, however, an agent's endowment is proportional to the aggregate endowment, then his value function is linear and he is indifferent about information: such an agent never trades and hence is insulated from the effects of information.[26]

One may wonder whether the strong unanimity conclusion of Theorem 2 might be extended to a broader class of economies. We now present an example in which the two agents have different constant relative risk-aversion preferences, yet one agent sometimes benefits *ex ante* from better information. Hence, the scope for such extensions would seem to be limited.

Example 2: Let there be two states with $\omega(2) = 10$ and $\omega(1) = 1$ and let $(p, 1 - p)$ be the probability vector. Let agent 1 own all the state 1 wealth and have log utility, $u_1(c) = \ln(c)$; let agent 2 own all state 2 wealth and have constant relative risk aversion utility $u_2(c) = -c^{-1}$. The equilibrium price of good 1 is $r(p) = (1 + 18p + p^2 - (1 - p)\sqrt{1 + 38p + p^2})(2(1 -$

[25] The Cobb-Douglas limiting case ($\alpha = 0$) gives a simple value function: $V(p) = \ln(\Sigma\ p_S(\omega(s, i)/\omega(s)) + \Sigma\ p_S \ln\ \omega(i, s)$, where the summations are across states. As long as i's endowment is not proportional to the aggregate in any pair of states, this function is strictly concave in p.

[26] This last observation provides a counterexample to the last sentence of Green's (1981) Theorem in Section 4.C, which asserts that if all agents have strictly concave utilities, then an improvement in the information structure starting from no information must make at least one agent worse off.

$p)p)^{-1}$ (after normalizing the price of good 2 to unity). Agent 1's final consumption in state 1 is p and in state 2 is $(1 - p)r(p)$. His value function from the equilibrium is thus $V_1(p) = p \ln(p) + (1 - p)\ln(1 - p) + (1 - p)\ln(r(p))$. One may verify that this function is strictly convex in p on an interval containing 1. By Lemma 1, this agent sometimes likes better information.[27]

Indeed, Berk and Uhlig (1993) analyze a dynamic exchange economy under uncertainty in which there is a positive mass of agents who prefer better information. In their economy, consumption takes place in only the last period, but information is gradually revealed in earlier periods. They ask whether some agents would prefer that information be revealed sooner rather than later. They find that an agent who simply consumes his endowment under the less informative structure prefers the early release of information. A comparison with our Example 1 is illuminating: there an agent who has an endowment proportional to the aggregate endowment never trades; yet such an agent is always precisely indifferent about information.[28] Besides being a dynamic model, an important difference between their model and ours is how trading takes place. We assume that there are markets for the single physical good in each state. They, however, assume that spot markets exist only in the final period (after some states are no longer possible) but add a pair of long-lived assets that are traded in each period. In light of our contrasting conclusions, an important research topic is to determine how the mechanism for sharing risk affects the comparative statics of improved information.

[27] The important qualitative facts are that agent 1 owns all of the relatively scarce state 1 wealth and agent 2 is more risk averse. Indeed, if agent 2 is replaced with an "infinitely" risk-averse maximin agent (who evaluates consumption plans by the worst component, $\min\{c1, c2\}$) then agent 1 *always* likes more public information. This example, however, lies outside our framework since a maximin agent does not satisfy expected utility.

[28] More generally, if a representative agent exists and an agent does not trade under null information, that agent is indifferent about better information.

IV. Further Examples and Applications

Theorem 2 considers only exchange economies. If there is production, then public information may or may not be valuable even if there is a representative agent: a trade-off arises between the deleterious effect of information on risk sharing and the improved allocation of inputs. Eckwert and Zilcha (1999) examine this trade-off in a dynamic model with production and identical risk-averse consumers. In particular, information is valuable in their model if risk-sharing markets are absent; but may be of positive or negative value if risk-sharing markets are active.[29] (Risk sharing occurs through risk-neutral firms.) Example 3 illustrates in a simple static production economy that the value of information can still be negative for every agent, even though that information is useful in allocating inputs and the representative agent strictly prefers better information.

Example 3: Let there be two agents, each endowed with 1 unit of labor (ℓ) that they supply inelastically. Each agent owns a single plot of land. There are two equally likely states of nature and the production technology on agent i's plot in state s is given by $f_{is}(\ell) = 0$ if $s \neq i$; if $s = i$ then $f_{is}(\ell) = \ell$ if $\ell \leq 1$ and $f_{is}(\ell) = 0.75 + 0.25\ell$ if $\ell > 1$. (That is, agent i's plot is only productive in state i.) Assume that unless information is perfect, labor must be applied to a plot before learning the state, and that agent i's von Neumann-Morgenstern utility is $u_i(c) = (1/\alpha)c^{\alpha}$, $0 \neq \alpha < 1$, $i = 1, 2$. We will compare null vs. perfect information. Normalize the price of labor to 1. With no information, the price of consumption in each state will be between 1 and 4, and each agent will consume half a unit in each state. With perfect information, if the state is i, then the price of state i consumption will equal 4, agent i will consume 1 unit and the other agent will consume 0.25 units. The welfare comparison between the two information systems depends on the risk-aversion parameter α. For $\alpha > 0$ the agents prefer perfect information. For $\alpha < 0$,

[29] Schlee (1996) shows that the aggregate value of information about product quality is positive under perfect competition in the absence of risk-sharing markets.

however, they prefer no information. The representative agent, however, always strictly prefers information, since it views a sure aggregate consumption of 1.25 as better than an aggregate consumption of 1.

Thus, in a production economy, our analysis has two implications. First, the value of public information can still be negative. Second, even if some or all agents value information, a representative-agent approach may badly misstate the welfare consequences of improved information. Note, however, that the representative agent in the example is perfectly valid for calculating equilibrium prices and aggregate consumption.

Representative-agent models are of course widely used in macroeconomics. Lucas (1987 Chapter 2) used one to measure the welfare costs of business-cycle fluctuations. He calculated the expected utility of a single agent under two scenarios: one with random consumption fluctuations chosen to match aspects of postwar consumption variability, and one with consumption stabilized at a particular realization. He found the welfare cost of uncertainty to be low, and used that calculation to suggest that learning about business cycles will not raise welfare much. A closely related calculation is a pure value of information one. For that calculation we do not know *ex ante* what *particular* nonstochastic consumption stream agents will experience. Instead, we calculate the optimal consumption path for *each* possible sequence of shocks and use the prior belief to calculate the resulting *ex ante* expected utility with information; this number we compare with expected utility without additional information. Our framework clearly differs from that of real-business-cycle models. Nevertheless our analysis suggests that a representative-agent model is apt to misstate the welfare gain from learning about business cycles if household incomes are (imperfectly) correlated with aggregate shocks and households share risks.

Another potential application is to the literature on optimal growth and experimentation. Most applications of optimal growth models under uncertainty exclude the possibility that the planner can experiment to learn more about the relationship between aggregate investment and aggregate output: either the aggregate technology shocks are assumed to be independently and identically distributed, so that there is nothing to learn; or the planner is assumed to observe the shock realizations directly, so that the investment level does not affect how much the planner learns. Several papers, however, have considered growth models in which the planner not only learns about the technology, but also can affect how much he learns by varying investment (Xavier Freixas, 1981; Mahmoud A. El-Gamal and Rangarajan K. Sundaram, 1993; Graziella Bertocchi and Michael Spagat, 1998; Manjira Datta et al., 2000). The planner may sacrifice current utility to affect how much information is available for the future. Now, as long as the utility function over aggregate consumption plans simply describes the preferences of a policy maker, then our analysis has nothing to say about this purely positive interpretation. But if the utility function is taken to be that of a representative agent, then the model may no longer be one of *optimal* growth, since the representative agent may overvalue information relative to the actual agents in the economy.

V. Conclusion

Since Hirshleifer (1971), we have known that better information sometimes makes some agents worse off in a competitive equilibrium allocation of risk. We have given conditions ensuring that *all* agents dislike *any* improvement in information. The most interesting condition is that the economy has a positive representative agent. In this case the representative agent is Pareto inconsistent: although each agent dislikes information, the representative agent is always indifferent. This result is interesting since applications often assume that a representative agent exists. Of course, such applications also typically involve production as well as risk sharing, and we have focused on the latter. Nevertheless, our finding suggest that representative-agent models might seriously misstate the welfare consequences of improved information, even though the model may be valid from a purely positive viewpoint.

In our analysis, we assumed that agents could not insure against the effects of information. Of course if the value of public information is negative, then agents have an incentive to mitigate its effects. In particular, they might refuse to produce it, or take actions to prevent others from using it. We noted in the introduction that individuals often refuse free genetic testing, and that they often cite the fear of the information becoming public as a reason for not getting tested. Partly in response to similar fears, many states have passed legislation to ban insurance companies from "genetic discrimination," and several such bills are under consideration in the U.S. Congress. Political support for such measures is consistent with the view that—given existing risk-sharing institutions—the value of information about genetic status for many individuals is negative.

Appendix A: Comparing Information Structures

Blackwell (1953) showed that the following statistical definition of more information was equivalent to an economic version that says that every decision maker would prefer to observe the more informative of two experiments.

Definition: Information structure $\mathbf{q}$ is more informative than $\mathbf{q}'$ if there are numbers $\{g(z', z)\}_{z,z' \in Z\}}$ such that for every s, and z' in Z we have $q_s'(z') = \Sigma_{z \in Z}\, g(z', z) q_S(z)$ and $1 = \Sigma_{z' \in Z}\, g(z', z)$.

Intuitively, we can interpret the function $g(\cdot, \cdot)$ as a transition probability: the less informative structure is a "garbling" of the more informative in the sense that each realization from the more informative structure is randomized according to the probability function $g(\cdot, \cdot)$. Hence, the more informative structure is *sufficient* for the less informative.

This garbling condition is sometimes tedious to apply directly. The following lemma asserts that this definition is equivalent to a much more convenient property: the more informative of two structures raises the expectation of any convex function of posterior beliefs.[30]

LEMMA: *Information structure* $\mathbf{q}$ *is more informative than* $\mathbf{q}'$ *if and only if for every convex function* $F(\cdot)$ *on the set of probability distributions over* $\{1, \ldots, S\}$, $\Sigma_{z \in Z} F(p(\cdot|z, \mathbf{q}'))\lambda(z, \mathbf{q}') \leq \Sigma_{z \in Z} F(p(\cdot|z, \mathbf{q}))\lambda(z, \mathbf{q})$ *where* $\lambda(z, \mathbf{q})$ *is the prior probability of* z *under information structure* $\mathbf{q}$ *(and prior belief* π*).*

[30] Richard E. Kihlstrom (1984) gives a clear proof of the lemma and explains the relationship between various definitions of a more informative experiment.

This result gives a simple way to determine whether an agent likes or dislikes information. Let $c^*(s, i; p)$ denote agent i's consumption in state s from an allocation rule $A(\cdot)$ when his beliefs are p and let $V_i(p)$ denote the corresponding value function: $V_i(p) = \Sigma_{s=1}^{S} u_i(c^*(s, i; p))p(s)$. According to the lemma, an agent will like information if this value function is convex in p, and will always dislike information if its value function is concave in p. Intuitively, an increase in information increases the riskiness of the *ex ante* distribution of posterior beliefs; if the value function is concave, its expectation falls with such an increase in risk. For example, let the probability distribution over states of nature be p'' with probability μ, and p' with probability $1 - \mu$. Without further information, an agent's expected utility from the allocation rule is $V_i(\mu p'' + (1 - \mu)p')$; if, however, the agent learns the distribution before the allocation is chosen, then his *ex ante* expected utility is $\mu V_i(p'') + (1 - \mu)V_i(p')$. The last expression is smaller than $V_i(\mu p'' + (1 - \mu)p')$ if and only if V_i is concave. Thus, we can show that an agent dislikes information for an allocation rule merely by showing that the agent's value function from that rule is concave in beliefs.

Appendix B: Proofs

PROOF OF THEOREM 1:

Let $\mathcal{U}(\mathbf{q})$ be the *ex ante* expected utility possibilities set for information structure $\mathbf{q}$. Let $c(s, i, z; \mathbf{q})$ be i's consumption in state s upon observing z under $\mathbf{q}$ and suppose for each $\mathbf{q}$ and z this constitutes an allocation. We will show that $\mathcal{U}(\mathbf{q}^*) = \mathcal{U}(\mathbf{q})$ for all $\mathbf{q}$, where $\mathbf{q}^*$ is a perfect information structure. To begin we may write agent i's *ex ante* utility under $\mathbf{q}^*$ as

$$\sum_{z \in Z}\left(\sum_{s=1}^{S} u_i(c(s, i, z, \mathbf{q}^*))p(s|z; \mathbf{q}^*)\right)\lambda(z; \mathbf{q}^*)$$
$$= \sum_{s=1}^{S} u_i(c(s, i, \psi(s), \mathbf{q}^*))\pi(s).$$

where $\lambda(z; \mathbf{q}^*) = \Sigma_{\sigma=1}^{S} \pi(\sigma)q_\sigma^*(z)$, the prior probability that signal z is realized and, for each s, $\psi(s)$ denotes the unique element of Z with $q_s^*(z) = 1 = p(s|z, \mathbf{q}^*)$.

Agent i's *ex ante* utility from any information structure q is

$$\text{(B1)} \quad \sum_{z \in Z} \left(\sum_{s=1}^{S} u_i(c(s, i, z, \mathbf{q}))p(s|z) \right) \lambda(z; \mathbf{q})$$

$$= \sum_{s=1}^{S} \left(\sum_{z \in Z} u_i(c(s, i, z, \mathbf{q}))q_s(z) \right) \pi(s).$$

First we must have $\mathcal{U}(\mathbf{q}^*) \subseteq \mathcal{U}(\mathbf{q})$ for any $\mathbf{q}$, which follows by setting $c(s, i, z, \mathbf{q}) = c(s, i, \psi(s), \mathbf{q}^*)$ for all s and z. To show that $\mathcal{U}(\mathbf{q}) \subseteq \mathcal{U}(\mathbf{q}^*)$ for any $\mathbf{q}$, observe that, by risk aversion, we have for each agent i that the right side of (B1) is no larger than $\Sigma_{s=1}^{S} u_i(\Sigma_{z \in Z} c(s, i, z, \mathbf{q})q_S(z))\pi(s)$. Since $\Sigma_{i=1}^{n} c(s, i, z, \mathbf{q}) \leq \omega(s)$ for all s, the following constitutes an allocation for a perfect information structure: $c^*(s, i) = \Sigma_{z \in Z} c(s, i, z, \mathbf{q})\mathbf{q}(z|s)$ for all s and i. So any vector of *ex ante* expected utilities in $\mathcal{U}(\mathbf{q})$ must be in $\mathcal{U}(\mathbf{q}^*)$.

PROOF OF THEOREM 2:

First, note that in each of the three scenarios, for any signal realization from any information structure $\mathbf{q}$, both the equilibrium price vector and allocation for each risk-averse agent are unique. Second, the demands and hence the equilibrium allocation for any signal realization depend merely on posterior beliefs. Thus, the expected utility for an agent in a competitive equilibrium from a signal realization z from $\mathbf{q}$ is given by a value function $V_i(p(\cdot|z; \mathbf{q})) = \Sigma_{s=1}^{S} u_i(c^*(s, i, p(\cdot|z; \mathbf{q})))p(s|z; \mathbf{q})$, where c^* is the equilibrium allocation implied by the posterior belief $p(\cdot|z; \mathbf{q})$. By the lemma, an agent will always dislike more information if his value function is a concave function of beliefs.

For case (i) and (ii) the unique equilibrium price vector equals the vector of state probabilities and the allocation involves full insurance for every risk-averse agent. Thus if the probability distribution over the states of the world is $p(\cdot)$, any risk-averse agent i's value function from the equilibrium is $V_i(\mathbf{p}) = u_i(\Sigma_{s=1}^{S} \omega(s, i)p(s))$, which is concave in $\mathbf{p}$ by risk aversion, and strictly concave as long as the endowment is random. Thus, if the initial endowment is random, then for (i) all agents are hurt by better information; for (ii), all risk-averse agents are hurt by better information.

For (iii), let $c^*(s, i, \mathbf{p})$ be the equilibrium consumption of agent i in state s when beliefs are given by $\mathbf{p}$. Let $\mathbf{p}'$ and $\mathbf{p}''$ be two distinct probabilities, let $\lambda \in (0, 1)$ and let $\boldsymbol{\pi} = \lambda\mathbf{p}'' + (1 - \lambda)\mathbf{p}'$. We will show that $V_i(\boldsymbol{\pi}) \geq \lambda V_i(\mathbf{p}'') + (1 - \lambda)V_i(\mathbf{p}')$. Let $U(\cdot)$ be the von Neuman-Morgenstern utility of the representative agent. For any $\mathbf{p}$, an equilibrium price vector is given by $r(s; p) = U'(\omega(s))p(s)$ for $s = 1, \ldots, S$. Note that $\mathbf{r}(s; \pi) = \lambda\mathbf{r}(s; \mathbf{p}'') + (1 - \lambda)\mathbf{r}(s; \mathbf{p}')$ for every state. Define, for $\pi(s) \neq 0$,

$$c^{**}(s, i) = \frac{\lambda c^*(s, i, \mathbf{p}'')p''(s) + (1 - \lambda)c^*(s, i, \mathbf{p}')p'(s)}{\lambda p''(s) + (1 - \lambda)p'(s)}.$$

The following string of inequalities implies that this "averaged" consumption $(c^{**}(1, i), \ldots, c^{**}(S, i))$ is affordable for each consumer at the equilibrium price vector when $\mathbf{p} = \boldsymbol{\pi}$:

$$\sum_{s=1}^{S} r(s, \boldsymbol{\pi})c^{**}(s, i)$$

$$= \sum_{s=1}^{S} [U'(\omega(s))(\lambda c^*(s, i, \mathbf{p}'')p''(s) + (1 - \lambda)c^*(s, i, \mathbf{p}')p'(s))]$$

$$= \lambda \sum_{s=1}^{S} [r(s, \mathbf{p}'')c^*(s, i, \mathbf{p}'') + (1 - \lambda) \sum_{s=1}^{S} r(s, \mathbf{p}')c^*(s, i, \mathbf{p}')]$$

$$\leq \lambda \sum_{s=1}^{S} [r(s, \mathbf{p}'')\omega(s, i) + (1 - \lambda) \sum_{s=1}^{S} r(s, \mathbf{p}')\omega(s, i)]$$

$$= \sum_{s=1}^{S} r(s, \pi)\omega(s, i).$$

Now

$$\lambda V_i(\mathbf{p}'') + (1-\lambda)V_i(\mathbf{p}')$$
$$= \lambda \sum_{s=1}^{S} u_i(c^*(s, i, \mathbf{p}''))p''(s)$$
$$+ (1-\lambda) \sum_{s=1}^{S} u_i(c^*(s, i, \mathbf{p}'))p'(s)$$
$$= \sum_{s=1}^{S} [(\lambda u_i(c^*(s, i, \mathbf{p}''))p''(s)$$
$$+ (1-\lambda)u_i(c^*(s, i, \mathbf{p}'))p'(s))]$$
$$\leq \sum_{s=1}^{S} [u_i(c^{**}(s, i))$$
$$\times (\lambda p''(s) + (1-\lambda)p'(s))]$$
$$= \sum_{s=1}^{S} u_i(c^{**}(s, i))\pi(s) \leq V_i(\boldsymbol{\pi}).$$

The last inequality follows from affordability of $(c^{**}(1, i), \ldots, c^{**}(S, i))$ at prices $\mathbf{r}(\boldsymbol{\pi})$, and the one preceding it follows from risk aversion and the definition of c^{**}. Thus each agent's value function is concave in beliefs; by the lemma each always dislikes more information.

REFERENCES

Berk, Jonathan B. and Uhlig, Harald. "The Timing of Information in a General Equilibrium Framework." *Journal of Economic Theory*, April 1993, *59*(2), pp. 275–87.

Bertocchi, Graziella and Spagat, Michael. "Growth under Uncertainty with Experimentation." *Journal of Economic Dynamics and Control*, November 1998, *23*(2), pp. 209–31.

Blackwell, David. "Equivalent Comparison of Experiments." *Annals of Mathematical Statistics*, June 1953, *24*(2), pp. 265–73.

Boyer, Marcel; Dionne, George and Kihlstrom, Richard E. "Insurance and the Value of Publicly Available Information," in Thomas B. Fomby and Tae Kun Seo, eds., *Studies in the economics of uncertainty*. New York: Springer-Verlag, 1989, pp. 137–55.

Brennan, M. J. and Krauss, Alan. "Necessary Conditions for Aggregation in Securities Markets." *Journal of Financial and Quantitative Analysis*, September 1978, *13*(3), pp. 407–08.

Crocker, Keith J. and Snow, Arthur. "The Social Value of Hidden Information in Adverse Selection Economies." *Journal of Public Economics*, August 1992, *48*(3), pp. 317–47.

Datta, Manjira; Mirman, Leonard J. and Schlee, Edward E. "Optimal Experimentation in Signal Dependent Decision Problems." Working paper, Arizona State University, January 2000.

Deaton, Angus and Muellbauer, John. *Economics and consumer behavior*. Cambridge: Cambridge University Press, 1980.

Doherty, Neil A. and Thistle, Paul D. "Adverse Selection with Endogenous Information in Insurance Markets." *Journal of Public Economics*, December 1996, *63*(1), pp. 83–102.

Dow, James and da Costa Werlang, Sérgio Ribeiro. "The Consistency of Welfare Judgments with a Representative Consumer." *Journal of Economic Theory*, April 1988, *44*(2), pp. 269–80.

Eckwert, Bernard and Zilcha, Itzhak. "Incomplete Risk Sharing Arrangements and the Value of Information," Foerder Institute Working Paper No. 13-99, Tel Aviv University, 1999.

Eisenberg, E. "Aggregation of Utility Functions." *Management Science*, July 1961, *7*(4), pp. 337–50.

El-Gamal, Mahmoud A. and Sundaram, Rangarajan K. "Bayesian Economists ... Bayesian Agents: An Alternative Approach to Optimal Learning." *Journal of Economic Dynamics and Control*, May 1993, *17*(3), pp. 355–83.

Freixas, Xavier. "Optimal Growth with Experimentation." *Journal of Economic Theory*, April 1981, *24*(2), pp. 296–309.

Gorman, W. M. "Community Preference Fields." *Econometrica*, January 1953, *21*(1), pp. 63–80.

Green, Jerry R. "Value of Information with Sequential Futures Markets." *Econometrica*, March 1981, *49*(2), pp. 335–58.

Hakansson, Nils H.; Kunkel, J. Gregory and Ohlson, James A. "Sufficient and Necessary Conditions for Information to Have Social Value in Pure Exchange." *Journal of Finance*, December 1982, *37*(5), pp. 1169–81.

Harrington, Joseph E., Jr. "Experimentation and Learning in a Differentiated-Products Duopoly." *Journal of Economic Theory*, June 1995, *66*(1), pp. 275–88.

Hirshleifer, Jack. "The Private and Social Value of Information and the Reward to Inventive Activity." *American Economic Review*, September 1971, *61*(4), pp. 561–74.

Jerison, Michael. "Social Welfare and the Unrepresentative Representative Consumer." Working paper, State University of New York, September 1984.

______. "Nonrepresentative Representative Consumers." Working paper, State University of New York, March 1996.

Kihlstrom, Richard E. "A 'Bayesian' Exposition of Blackwell's Theorem on the Comparison of Experiments," in Marcel Boyer and Richard E. Kihlstrom, eds., *Bayesian models of economic theory*. New York: Elsevier, 1984, pp. 13–31.

Kirman, Alan P. "Whom or What Does the Representative Individual Represent?" *Journal of Economic Perspectives*, Spring 1992, *6*(2), pp. 117–36.

Lerman, Caryn et al. "BRCA1 Testing in Families with Hereditary Breast-Ovarian Cancer." *Journal of the American Medical Association*, June 1996, *275*(24), pp. 1885–92.

Lucas, Robert E., Jr. *Models of business cycles*. New York: Blackwell, 1987.

Marshall, John M. "Private Incentives and Public Information." *American Economic Review*, June 1974, *64*(3), pp. 373–90.

Mas-Colell, Andreu; Whinston, Michael D. and Green, Jerry R. *Microeconomic theory*. Oxford: Oxford University Press, 1995.

Mirman, Leonard J.; Samuelson, Larry and Schlee, Edward E. "Strategic Information Manipulation in Duopolies." *Journal of Economic Theory*, April 1994, *62*(2), pp. 363–84.

Quaid, Kimberly A. and Morris, Michael. "Reluctance to Undergo Predictive Testing for Huntington's Disease." *American Journal of Medical Genetics*, January 1993, *45*(1), pp. 41–45.

Rothschild, Michael and Stiglitz, Joseph E. "Increasing Risk: I. A Definition." *Journal of Economic Theory*, September 1970, *2*(3), pp. 225–43.

______. "Competition and Insurance Twenty Years Later." *Geneva Papers on Risk and Insurance Theory*, December 1997, *22*(2), pp. 73–79.

Samuelson, Paul A. "Social Indifference Curves." *Quarterly Journal of Economics*, February 1956, *70*(1), pp. 1–22.

Schlee, Edward E. "The Value of Information about Product Quality." *Rand Journal of Economics*, Winter 1996, *27*(4), pp. 803–15.

Sulganik, Eyal and Zilcha, Itzhak. "The Value of Information in the Presence of Futures Markets." *Journal of Futures Markets*, April 1996, *16*(2), pp. 227–40.

Townsend, Robert M. *The medieval village economy: A study of the Pareto mapping in general equilibrium models*. Princeton, NJ: Princeton University Press, 1993.

Wilson, Robert. "Informational Economies of Scale." *Bell Journal of Economics*, Spring 1975, *6*(1), pp. 184–95.