Consumption of Economic Information in Agriculture

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We develop a model of decision makers' demand for agricultural economic information services. This model treats choice of external decision-support services as a function of actors' assessment of how alternative investments in information complement their internal competencies. Data from a survey in four commodity systems are used to evaluate hypotheses as to how human capital, and functional role of actors in commodity systems affect demand for variously formatted information. By focusing on three axes of heterogeneity—diversity among decision makers, information service providers, and information—we are able to identify key structural and functional relationships in agricultural economic information systems.

Key words: information, uncertainty, value of information.

Beginning with Adam Smith, economists have recognized that information availability is a crucial component of efficient markets. Governments have assumed an important role in providing economic information to decision makers in agriculture. Through the Economic Research Service (ERS) and the National Agricultural Statistical Service (NASS), the U.S. Department of Agriculture (USDA) has long been the primary producer of agricultural economic information in the United States. However, commodity associations, private consultants, neighbors, and Extension represent important additional sources of information. In addition to fee-based and publicly provided services, some of this information is obtained informally through social and professional interaction or is a by-product of economic transactions. In the context of structural and organizational change in agriculture, explosion of information technology, growing sophistication of decision makers and their advisers, and shifts in conceptions of the appropriate role of the state in the economy, some have questioned the role of public and private sector actors in providing agricultural economic information services (e.g., Bonnen; Just; Wolf, Just, and Zilberman 2001; Salin et al.).

As government agencies reevaluate their data and information provision activities (AAEA Data Task Force), it has become clear that we lack the basic understanding of use patterns, the roles of different types of information, and the relationship between private and public data provision. Without quantitative analysis of patterns of use of information services and theoretical guidance as to principles governing the structure and function of information systems, policymaking capacity will be limited.

Economists have developed a framework to study the value of information in specific contexts. Typically, profits in the absence of information are compared to profits when information is available to estimate the value of information. Babcock used the economic decision-making framework of Marschak to study the value of weather information in production. He showed that farmers individually might gain from information, but the sector as a whole may lose because of the supply-enhancing effect of updating. Sumner and Mueller have studied the effect of USDA harvest forecast on futures prices. Each of these studies analyzed the value of a particular type of information to a particular group of individuals, most often farmers, each of

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whom is presumed to be wrestling with the identical problem.

Here we evaluate the patterns of usage of several information types rather than the value of a single type of information. We seek to integrate consideration of diversity among users of agricultural information as well as the uncertainty they face. Our framework simultaneously applies to farmers, input suppliers, commodity traders, farm magazine editors, extension agents, and others engaged in commodity systems. Their informational needs include prediction of prices, supply and demand estimates, information about the performance of alternative technologies, discussion and strategic advice as to implications of regulations and trade policies, and information about changing dietary patterns and retail trends. Furthermore, information may come in a variety of forms including large databases and small numbers of prescriptive directives targeted to specific individuals. These variously formatted information services may be provided by private vendors, public agencies, or through informal channels. Here, we are not explicitly assessing the value of each type of information, but rather, the pattern of use of each type of information and the economic logic that underlies these patterns. We employ an expected utility approach to evaluate the economic nature of information use decisions. Our econometric analysis is derived from an economic decision-making framework that views information as an economic input (Stigler). We argue that decision makers must choose the extent to which they rely on a certain type of information.

In this article, we develop a model of individual decision makers' demand for heterogeneous information services and derive hypotheses to explore key research and policy questions. Data from a survey in four commodity systems are used to evaluate hypotheses. By focusing on three axes of heterogeneity—diversity among decision makers, information service providers, and information—we are able to identify key structural and functional relationships in information systems. Our approach serves to produce a description of how attributes of decision makers and the context in which they must allocate resources under uncertainty affect demand for different information services. This analytic framework informs our understanding of the observed division of labor in agricultural economic information systems.

The ability to access and process information and produce knowledge are increasingly recognized as critical determinants of economic performance of firms, sectors, regions, and national economies (e.g., Edquist). The starting point of our analysis is that agricultural businesses are decision-making units with the capacity to make use of their own experience and knowledge, as well as take advantage of externally sourced information. Our results show heavy use of publicly generated information among private information suppliers, a finding that directly reflects how specific competencies of various actors in commodity systems are reflected in the organization—i.e., functional specialization—of information systems. We find that the level of formal education of actors has a large influence on the nature of information sought and, in particular, use of publicly provided information. Informal channels are shown to be an extremely important communication pathway, particularly in settings where formal information is limited and actors actively cooperate.

Heterogeneity of Information and Information Users

Stiglitz (1974, 1985) argued that economic decisions are made under conditions of imperfect information. He developed models allowing actors to reduce their uncertainty through acquisition of additional information. Simon's bounded rationality models suggested that individuals face limitations on their ability to use, store, or retrieve information. Differences in individuals' capacity to process and assess the value of information lead to variability in consumption patterns, as some individuals will have little ability to use certain information, and thus weaker demand. Schultz developed the notion that human capital is based on education and experience and hypothesized that differences in people's ability to "deal with disequilibria" translate into variable performance under uncertainty. Simon and Schultz emphasized heterogeneity among information users. Here, we also consider heterogeneity along this axis, but we also address differences among decision contexts, information suppliers, and the information services they provide. Thus, information on a given topic can

be presented in a number of different ways by a variety of suppliers each geared toward more or less specific audiences. Allowing for variation in each of these axes positions us to model elements of observed organizational and behavioral complexity.

Production theory suggests that heterogeneous agents facing equivalent prices will use different input mixes. Thus, different decision makers will use varying amounts of different types of information. Each information provider packages their information with a different set of characteristics (e.g., content, communication style, media, frequency) reflecting both their own capabilities and their perception of the needs of their targeted clientele. Individual actors' choices as to which analytic services to seek out are presumed to reflect their efforts to complement existing in-house informational resources. In our short-run framework, actors' in-house analytic capabilities and absorptive capacity (Cohen and Levinthal) are considered to be inflexible. Of course, over the longer term, actors learn and invest in training, skilled personnel, organizational innovation, and tools to enhance their decision-making capacity. Clearly, such an evolutionary or adaptive approach is complementary to the static treatment pursued in this article.

We identify three dimensions of information inputs that allow us to analyze consumption of decision-support services. The first axis is the distinction between data and information. Data are relatively unprocessed or raw statements of fact. Information is defined as having been manipulated in some way. This distinction is similar to that made by Boehlje and allows us to analyze complex organizational relationships supporting transformation of generic information to differentiated decision support. In this article and in the surveys on which our empirical analysis is based, we define data as statistical representations of past or present status. We define information as analysis, synthesis, and interpretive reports. For example, a historical report of wheat prices is data, whereas a price forecast is considered information. Further, a discussion of how trade relations, fiscal policy, or development of bioengineered seeds will affect export opportunities is treated as information. Whereas acknowledging the arguably fuzzy boundary between data and information, we accept this ambiguity as we focus on the specific question of the distribution of analytic competencies in agricultural economic information networks.

The second dimension of information format we examine is the distinction between publicly and privately supplied information. We define public information as distributed by a public agency. Private information is distributed by private organizations, i.e., commercial firms such as consultants as well as collective organizations such as commodity associations. Like the previous distinction, there is an element of ambiguity as the provider of information is not always the producer of the information. Information is created through successive processes of adding value to existing data and information. In many cases, information provided to a decision maker by a commercial analyst represents a targeted analysis of publicly generated data or a synthesis of several existing reports. The cumulative nature of information and patterns of its circulation suggest that labels such as public and private can be misleading. Regardless, consideration of the extent to which actors rely on public and private service providers is useful for exploring the roles of these two broad classes of actors and their interdependencies.

The final axis we introduce here is the distinction between formal and informal information. For us, formal information is information obtained from entities, whose professional function is to provide information services. However clearly, much information used by agents to make decisions is not supplied by professional advisors. Agricultural markets are embedded in interpersonal networks constituting civic, domestic, professional, and commercial communities (Nohria and Eccles, Grannovetter and Swedburg). Neighbors, family, colleagues, customers, and suppliers are potentially important sources of guidance, particularly in settings where commitment to cooperation is high, information is too costly to purchase formally, or is unavailable via formal channels.

Analytic Framework

Actors in agricultural markets face many different types of uncertainty. Prices and yields may fluctuate due to climate and pest problems and political economic factors such as labor markets and trade regulations. Uncertainty in both production and markets

imparts value to information. Decision makers may use forecasts and reconnaissance to increase returns on investment and mitigate risks.

Information-sourcing decisions are generally modeled in terms of the value of information. The value of information is generally defined as the expected benefit from using the information. The notion of value of information has generally been used to model the choice between information sources, where each source is represented by a random signal. Each random signal is considered to have some joint distribution with a random variable representing the underlying uncertainty. In these models, all individuals are assumed to have the same capacity for information processing and thus the quality of the updating of expectations of future states of the world is equivalent across the range of actors (as in the models of Babcock and Blair and Romano).

In this article, we extend existing models of value of information by incorporating consideration of individuals' varying capacity to use differently formatted information and variation in their information needs. Specifically, we assume two factors affect ability to use, make sense of, and profitably apply information—human capital and functional role in a system of production (i.e., enterprise type or occupation). Because of human capital differences, some decision makers may be able to increase profits significantly through application of complicated datasets that other decision makers cannot decipher. With respect to enterprise type or occupation, timing and applicability of information will vary widely among actors facing different types of uncertainty.

Information services can be variably priced, formatted, and time-sensitive. Decision-support services with no fees exist, but even these involve search and processing costs. Acquiring, interpreting, and integrating external information with internal references requires analytic skills and time, which in some decision-making contexts are in short supply. By acknowledging these costs and their effect on analytic service use and provision, we are better able to understand structural and functional relations in information systems. By treating human capital and the functional role of actors as fixed factors, patterns of use of various types of information can be modeled.

We introduce our model by considering a decision maker engaged in a specific occupational role in a larger commodity system. This person facing some sort of underlying uncertainty may work directly in commodity production (i.e., farmer or processor) or be a service provider (Extension economist, agricultural journalist, strategic consultant). The decision maker's problem may be modeled in three stages (Marschak, Gould). Within the first stage, she must decide how much of each type of available information to acquire. For simplicity, we acknowledge only two types of information, so she must choose I_1 and I_2, where I_i is the stream of information of type i selected. The information types represent a source of uncertainty because the individual cannot know what information will result from any information type prior to acquisition. Within the second stage she processes the information, the information is gleaned, and she makes production decisions (such as amount of inputs and outputs). In the third stage, the state of the world is revealed and profits are realized.

As in dynamic programming, optimal behavior can be determined through backward induction. To understand the choice facing the individual in the first stage, we must first consider the second stage of our model, when production decisions are made given the information obtained from I_1 and I_2 as a result of choices made in the first stage. In this first stage, the decision maker faces the problem

$$(1) \qquad \max_{\mathbf{x}} \mathrm{EU}(\Pi(\mathbf{x}) \mid I_1, I_2, \gamma, \phi, h)$$

where $\mathrm{EU}(\cdot)$ is expected utility, Π is the quasi-rent with respect to information (because information is already processed in stage 2), $\mathbf{x}$ is a vector of inputs which may include physical inputs or processing resources, γ represents the decision maker's occupation within a commodity system (e.g., farmer, input supplier, Extension agent), ϕ represents the commodity system in which the firm participates and h is the firm's level of human capital. Despite the information purchased in stage one, some uncertainty may still exist in profits, and, hence, expected utility is appropriate. Because our model seeks to represent a broad range of information consumers, each of whom has more or less specific needs, $\mathbf{x}$ may represent any input. To the farmer, $\mathbf{x}$ may represent seed, fertilizer, or labor. For a commodity trader, $\mathbf{x}$ may

represent prices paid for futures contracts. In each case, **x** represents the decisions facing the firm after the information is revealed and updating is complete.

In period one, the effects of information purchases may be viewed as random, as the individual has not yet observed the information that she may purchase. By stage 2, however, the information is revealed and processed. Given any information bundle, (I_1, I_2), we assume problem (1) above to have a solution $\mathbf{x}^*$, or alternatively expected utility is maximized by the random variable $\Pi^*(I_1, I_2) = \Pi(\mathbf{x}^* | I_1, I_2)$.

We now turn to the first stage of the decision maker's problem. As is customary (Hirshleifer and Riley), we assume that the decision maker knows (or has subjective beliefs over based-on prior experience) the joint population distribution of the available information signals and the true underlying uncertainty. Knowledge of this distribution and the existence of a unique optimal expected utility in the second stage problem for each contingency allow us to model expected utility in stage one as a function of the choice of information. Suppose the decision-maker solves the following problem:

$$\max_{I_1, I_2} \mathrm{EU}(\Pi^*(I_1, I_2) - p_1 I_1 - p_2 I_2 \mid \gamma, \phi, h) \tag{2}$$

where p_i is the unit price of information type i. It is important to remember that $\Pi^*(I_1, I_2)$ denotes the random variable Π^*, whose distribution is dependent on the information purchased in stage one. The parameters of this distribution are themselves unknown, but we assume the individual has subjective beliefs as to the joint distributions of profit and information obtained from the choice of (I_1, I_2) and that this distribution is used in calculating expected utility. The distribution of Π^* will also depend on the human capital, h, or her ability to process the information she purchases.

It will be necessary to simplify our model somewhat to understand the impact of internal factors on information use. Freund has shown that, by assuming normally distributed profit and constant absolute risk aversion (Arrow), preferences may always be represented in the mean–variance form. Hence, we assume the following

1. Utility is of the exponential form, $U(\Pi) = 1 - e^{-r\Pi}$ (Arrow).
2. Uncertainty in profit is distributed such that

$$\Pi^*(I_1, I_2) \sim N(\mu(I_1, I_2 \mid \gamma, \phi, h), \sigma^2(I_1, I_2 \mid \gamma, \phi, h)).$$

Assumption 1 guarantees that individual's behavior displays constant absolute risk aversion. Assumption 2 guarantees that profits are distributed normally no matter which information bundle is used. Buying information cannot alter the population mean of the underlying uncertain events, but, if it is free, information will always weakly raise the mean of profits by allowing an individual to react to updated distributions of underlying random variables, contingent on the current state of the world. In our model, information may cost both money and resources.

We may now rewrite (2) as

$$\max_{I_1, I_2} \mu(I_1, I_2 \mid \gamma, \phi, h) - \frac{r}{2}\sigma^2(I_1, I_2 \mid \gamma, \phi, h) - p_1 I_1 - p_2 I_2. \tag{3}$$

The first two terms may be thought of as the return to information as this is the expected utility received if information were free. We can simplify (3) further by defining a function

$$R(I_1, I_2 \mid \gamma, \phi, h) = \mu(I_1, I_2 \mid \gamma, \phi, h) - \frac{r}{2}\sigma^2(I_1, I_2 \mid \gamma, \phi, h). \tag{4}$$

The first-order conditions for a solution to (3) are:

$$\frac{\partial \mu}{\partial I_i} - \frac{r}{2}\frac{\partial \sigma^2}{\partial I_i} = R_i = p_i \quad \text{for } i = 1, 2. \tag{5}$$

This problem will be solved by some information input levels $I_1^*(p_1, p_2, \gamma, \phi, h, r)$ and $I_2^*(p_1, p_2, \gamma, \phi, h, r)$. By simple division, we can define the relative use of type 1 information as $I_1/I_2 = f(p_1, p_2, \gamma, \phi, h, r)$, or, transforming logarithmically,

$$\ln \frac{I_1}{I_2} = \ln f(p_1, p_2, \gamma, \phi, h, r) = g(p_1, p_2, \gamma, \phi, h, r). \tag{6}$$

As is the case with all production inputs, complementarity and substitutability are critical concepts in modeling demand and supply. We will define information streams I_1 and I_2 as complements if $R_{12} > 0$, where R_{ij} denotes the cross-partial of R with respect

to information types i and j. If we assume the function R is twice continuously differentiable, then the order of differentiation does not matter and our notion of complement is well defined. We will say that I_1 and I_2 are substitutes if they are not complements.

Derivation of Hypotheses

Here we develop propositions that allow us to construct an empirical test of our model. We obtained data from a broad range of actors on their relative use of opposed sets of information (i.e., I_1/I_2); data vs. information, public vs. private, and formal vs. informal. Opposing these ideal information types allows us to compare analytic service consumption behaviors of actors with different internal information-processing resources and information requirements. Here we will derive the mathematical relations implied by our model. Let R_{ih} be the marginal effect of human capital on marginal rents to information of type i, and η_{jk} be the elasticity of demand for information type j with respect to the price of information type k.[1] Based on this definition, and by assuming certain bounds on the complementarity of information types, we obtain proposition 1.

PROPOSITION 1. *Under reasonable conditions,*[2] *we obtain* $(\partial \ln(I_1/I_2))/(\partial h) \geq 0$ *if and only if*

$$R_{1h} \geq \frac{p_1(\eta_{22} - \eta_{12})}{p_2(\eta_{11} - \eta_{21})} R_{2h}.$$

A proof of proposition 1 can be obtained from the authors. We assume that human capital is complementary to information ($R_{ih} > 0$), and thus enhances the productivity of both inputs. Define $MCH_{ij} \equiv R_{ih}/R_{jh}$ as the measure of relative complementarity to human capital of information type i vs. type j.

The ratio I_1/I_2 is a measure of intensity of relative use of the two opposed information formats. Proposition 1 suggests that we call information type i more human capital-intensive in consumption than type j (at the margin) when $R_{ih} \geq (p_i(\eta_{jj} - \eta_{ij})/p_j(\eta_{ii} - \eta_{ji}))R_{jh}$.[3] If prices and elasticities are identical, this suggests that information type i is more human capital-intensive in consumption than type j when $MCH_{ij} > 1$. In accordance with Schultz' treatment of human capital, decision makers may differ in their ability to process information on their own based on variation in their skills, experience, and training (analytic competence). Because of heterogeneity in human capital among individuals, we expect variation in the shares of information types accessed. Individuals with higher levels of education will use relatively more of the human capital-intensive information types. In effect, heterogeneity in analytic competencies among a population of economic actors serves as a selective barrier to more- or less-processed information. Actors with the requisite human capital can "decode" data themselves. Actors with lesser capabilities must rely on others for assistance or perhaps fall back on habits and decision rules (Hodgson). Other factors, such as time available for decision-making and the types of decisions to be made, will affect the information purchased by an organization.

In our framework, data are less refined and action-oriented than is information, and thus will require more human capital to process. On this basis, we expect that decision makers with higher levels of human capital will use a higher proportion of data (H1). Following a similar logic, we can say that private information, relative to public information, is "context-specific and decision-focused" (Boehlje). Private organizations create value through customizing, targeting, reformatting, and distributing information in ways that support the needs of more or less specific groups of users. In contrast, public information is general, seeks to be comprehensive, and is not intended to service the needs of small groups of localized decision makers. Thus, public information is often technical in the sense that it must be skillfully processed to yield targeted decision support. These observations lead us to suggest that individuals with higher levels of human capital will use a higher proportion of public information than private information (H2).

We have defined formal information as interpretations produced by professional analysts communicated through stable, rigid channels generally in the form of artifacts such as newsletters, reports, or e-mail messages. Informal information is defined as interpretations communicated orally between people who are members of a more or less

[1] The demand for information type k is the amount I_k that satisfies equation (21). The price elasticity referred to is $\eta_{jk} = (\partial I_j/\partial p_k)(p_k/I_j)$.

[2] To obtain this result, we must assume $R_{12} < |R_{22}I_2/I_1|$ and $R_{12} < |R_{11}I_1/I_2|$. Essentially, the information types are not so complementary as to overcome the effect of diminishing returns.

[3] This definition of intensity is in opposition to that used in the international trade literature, but is much more convenient for our purposes.

Table 1. Summary of Research Hypotheses

	Information Format					
Organizational Resources	Data	Information	Public	Private	Formal	Informal
Human capital	+	−	+	−	+	+
		(H1)		(H2)		(H3)

well-defined community. Based on these definitions, we can say several things about these two formats. By virtue of the sender and receiver of informal information being linked through geography, line of work, and repeated interaction, informal information is more finely targeted to the needs of specific audiences. However, because informal sources as defined here are not professional analysts, their perspective may be provincial, the ability to consider future states of the world may be limited, and there may be only weak capacity to hold them accountable for poor or biased analysis (i.e., social sanctions). Thus, formal information is human-capital intensive in consumption, and organizations able to process information themselves—transform sets of general observations into targeted intelligence—are more likely to seek formal information (H3). Table 1 summarizes these hypotheses.

In summary, we argue that the resources of organizations and the environment in which they function shape their demand for variously formatted information. More specifically, the human capital or organizational role determines the extent to which it seeks information inputs which are processed according to their particular needs. Organizations with abundant analytic competencies are expected to prefer "raw", unprocessed inputs, whereas firms with relatively less human capital will seek out targeted decision support. In the next section, we evaluate these claims.

Data Collection and Statistical Methodology

Data were collected through both face-to-face and mail surveys in four commodity systems—Washington potatoes, Washington wheat, Iowa hogs, and California fresh tomatoes. Our approach is to capture some of the tremendous diversity in agriculture by selecting strongly contrasting commodity cases in terms of market size and geography, export intensity, perishability and form of final goods, use of contracting (Wolf, Just, and Zilberman, 1998, for more detail), and collecting data from many differently positioned actors in these systems. Thus, our data represent a rich cross-section rather than a strongly representative sample, and our results should be interpreted accordingly. Individuals working at multiple levels of the commodity chains were asked to identify their sources of agricultural economic information. Subsequently, these information providers were surveyed by mail (response rate = 58%, instrument available upon request from authors) to determine which information services they use. Generally, questionnaires were completed by the owner or on-site manager. This two-stage process generated 221 responses.

In addition to dividing respondents according to their commodity focus, we identify each as either an intermediary or enduser. We call anyone who seeks information for the purpose of processing and retransmission an intermediary. We further divide the category of intermediaries into securities brokers, commodity associations, agricultural media, commercial information vendors, agricultural extension agents, in-house analysts, and miscellaneous intermediaries. We call anyone who seeks information for supporting resource allocation decisions in their agricultural business an enduser. Endusers are divided into the following classes: wheat farmer, wheat elevator, wheat exporter, potato grower/packer/shipper, potato processor, hog farmer, hog processor, hog input supplier, tomato grower/packer/shipper, tomato input supplier, bank,[4] and miscellaneous enduser. These categories allow us to compare behaviors across classes of actors and identify general relationships, but within-group structural and behavioral heterogeneity must not be disregarded and, in fact,

[4] For our purposes, bankers are treated as input suppliers and are therefore classified as endusers. This decision is supported by empirical results presented in the article.

should be recognized as an important finding of our study.

Entities within each class vary according to size, organization, and product/service orientation, and we observe important differences in their information-sourcing behaviors.

We turn now to the statistical model of how the functional role in commodity systems and human capital affect use of information. By using a first-order approximation of (6) with respect to human capital, commodity, and role (commodity and role being discrete) about (γ_0, ϕ_0, h_0), we obtain

$$\ln\frac{I_1}{I_2} = g(p_1, p_2, \gamma_0, \phi_0, h_0, r) + g_h(p_1, p_2, \gamma_0, \phi_0, h_0, r)(h - h_0) + k_1\gamma + k_2\phi \tag{7}$$

where r represents the level of risk aversion (which we assume to be identical for all individuals), k_1 represents the difference in information use between occupation γ_0 and γ, k_2 represents the difference in information use between occupation ϕ_0 and ϕ, and γ and ϕ are dummy variables. We use data on the last degree of education completed to represent human capital. Thus, a linear approximation of (7) is

$$\ln\frac{I_1}{I_2} = \beta_0 + \beta_1\,\mathrm{HS} + \beta_2\,\mathrm{Col} + \beta_3\,\mathrm{Grad} + \beta_4\,\mathrm{Wheat} + \beta_5\,\mathrm{Potato} + \beta_6\,\mathrm{Hog} + \beta_7\,\mathrm{AB} + \beta_8\,\mathrm{Int}. \tag{8}$$

In this model, all values are compared to the base case of a tomato grower who has not completed high school. All right-hand side variables are dummy variables. HS is 1 if the respondent completed high school, Col is 1 if the individual completed some college, and Grad is 1 if the individual completed some graduate school. Thus, a respondent having completed college will have HS = 1, Col = 1, Grad = 0. Coefficients on the education variables represent the marginal effect of the diploma relative to the previous level of education. The variables, Wheat, Potato, and Hog are 1 if the individual is involved in the market for wheat, potatoes, or hogs, respectively. The variable AB takes the value 1 if the respondent is a nonfarm agribusiness.[5] Int takes the value 1 if the individual is an information-intermediary. We employ this model to evaluate differences in individuals' use of information formatted according to three axes presented earlier (data vs. information, public vs. private, formal vs. informal). It is likely that errors are correlated across the three equations, thus we estimate the following system using Zellner's seemingly unrelated regression (SUR) technique.

$$\ln\frac{\text{Data}}{\text{Info}} = \beta_0^1 + \beta_1^1\,\mathrm{HS} + \beta_2^1\,\mathrm{Col} + \beta_3^1\,\mathrm{Grad} + \beta_4^1\,\mathrm{Wheat} + \beta_5^1\,\mathrm{Potato} + \beta_6^1\,\mathrm{Hog} + \beta_7^1\,\mathrm{AB} + \beta_8^1\,\mathrm{Int} + \varepsilon^1 \tag{9}$$

$$\ln\frac{\text{Public}}{\text{Private}} = \beta_0^2 + \beta_1^2\,\mathrm{HS} + \beta_2^2\,\mathrm{Col} + \beta_3^2\,\mathrm{Grad} + \beta_4^2\,\mathrm{Wheat} + \beta_5^2\,\mathrm{Potato} + \beta_6^2\,\mathrm{Hog} + \beta_7^2\,\mathrm{AB} + \beta_8^2\,\mathrm{Int} + \varepsilon^2 \tag{10}$$

$$\ln\frac{\text{Formal}}{\text{Informal}} = \beta_0^3 + \beta_1^3\,\mathrm{HS} + \beta_2^3\,\mathrm{Col} + \beta_3^3\,\mathrm{Grad} + \beta_4^3\,\mathrm{Wheat} + \beta_5^3\,\mathrm{Potato} + \beta_6^3\,\mathrm{Hog} + \beta_7^3\,\mathrm{AB} + \beta_8^3\,\mathrm{Int} + \varepsilon^3. \tag{11}$$

The three dependent variables are ratios reflecting the relative proportion of differently formatted inputs. Data/Info summarizes a respondent's reliance on data vs. information.[6] Public/Private summarizes a respondent's reliance on publicly vs. privately supplied information. Finally, Formal/Informal summarizes reliance on formal vs. informal sources. Results are displayed in table 2 and will be discussed in the following section.[7]

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[5] We have aggregated upstream farm input suppliers and downstream processors and exporters into a single class of respondents, agribusiness (AB), and information suppliers into a class of respondents, intermediaries (Int). This aggregation highlights differences among farm, nonfarm, and information firms in commodity chains. Although we recognize within group heterogeneity, groupings are based on theory, as functional role in commodity system is viewed as a key determinant of the nature of uncertainty facing actors and their internal competencies. *F*-tests on complete regressions confirm that there are no significant differences within groups for the purposes of our estimation.

[6] Referring to the definitions stated earlier in the article, the questions were administered in the form: "Are you a heavier user of data or information? What percentage of your information is data and what percentage is information? The total equals 100%."

[7] A Breusch–Pagan test rejects the independence of residuals with a *p*-value of 0.001. Skewness-kurtosis tests for normality (D'Agostino, Balanger, and D'Agostino) fail to reject normality

Table 2. Results of Estimation

Variable	Parameter	*t*-Statistic	*p*-Value[a]
Data and information use $R^2 = 0.11$			
Intercept	0.3222	0.576	0.565
High school	−0.5782	−1.005	0.158
College	0.2470	1.288	0.099
Graduate school	0.0353	0.159	0.437
Wheat	−0.6228	−2.659	0.004
Potato	−0.6680	−2.529	0.006
Hogs	−0.3442	−1.497	0.068
Nonfarm agribusiness	0.3877	1.457	0.073
Information intermediary	0.2533	1.108	0.134
Public and private use $R^2 = 0.13$			
Intercept	−0.6687	−1.006	0.315
High school	−0.2166	−0.317	0.376
College	−0.0585	−0.257	0.399
Graduate school	0.5293	2.009	0.023
Wheat	−0.0206	−0.074	0.471
Potato	−0.4753	−1.515	0.065
Hogs	0.0291	0.107	0.458
Nonfarm agribusiness	0.0259	0.082	0.468
Information intermediary	0.7221	2.659	0.004
Formal and informal use $R^2 = 0.23$			
Intercept	−0.6056	−1.015	0.311
High school	1.0303	1.679	0.047
College	−0.0670	−0.327	0.372
Graduate school	0.2676	1.131	0.130
Wheat	−0.0458	−0.183	0.428
Potato	−0.9938	−3.526	0.000
Hogs	−0.1578	−0.644	0.260
Nonfarm agribusiness	0.0114	0.040	0.484
Information intermediary	0.8593	3.523	0.000

[a] All *p*-values are reported for one-tailed tests except for the intercept variable.

Results and Discussion

Data vs. Information

As table 3 indicates, people performing different jobs use varying amounts of information and data. Endusers use a higher proportion of information (56%) than do intermediaries (50%) ($p = 0.01$). This distribution conforms to our expectations as intermediaries exhibit higher levels of education relative to endusers. In fact, arranging classes of intermediaries by level of education yields the same ordering we obtain from ranking intermediaries according to proportion of data use. At the high end, we find Extension and in-house analysts, and at the low end, we find media. This result reflects the different functions and capabilities of actors in the general class of information intermediaries: some actors perform heavy analytic tasks whereas others focus on synthesis and dissemination of existing information (Wolf, Just, and Zilberman, 2001). In terms of endusers, we note that farm-level actors tend to use more information than off-farm agribusinesses, firms that presumably have a more specialized division of labor and greater analytic competence.

Table 3 confirms that intermediaries use more data than endusers, nonfarm agribusinesses use more data than farmers, and education is positively related to data use. Completion of college has the largest marginal impact on data use of any level

of residuals with *p*-values of 0.95, 0.67, and 0.61 for Data/Info, Public/Private, and Formal/Informal, respectively. Further, the Cook–Weisberg tests for heteroskedasticity across respondent groups fail to reject homoskedasticity with *p*-values of 0.43, 0.21, and 0.61, respectively. Estimation of the same system of equations using full-information maximum likelihood reveals no noticeable differences in estimates or significance of estimates.

Table 3. Education, Data Input, and Information Input of Endusers and Intermediaries

	Obs.	Education[a] (sd)	Data Input (%)	Information Input (sd) (%)
Endusers				
Wheat exporters	5	3.8 (1.0)	0.25	0.75 (0.13)
Wheat elevator	8	3.1 (1.0)	0.34	0.66 (0.55)
Wheat farmers	6	2.8 (1.0)	0.26	0.74 (0.13)
Potato processors	5	3.2 (1.1)	0.45	0.55 (0.22)
Potato grower/packer/shippers	6	2.1 (0.7)	0.39	0.61 (0.13)
Hog processors	4	3.5 (1.0)	0.61	0.39 (0.25)
Hog farmers	3	3.0 (0.0)	0.35	0.65 (0.18)
Hog input suppliers	2	2.5 (0.7)	0.60	0.40 (0.14)
Tomato input supplier	5	4.0 (1.0)	0.37	0.63 (0.20)
Tomato grower/packer/shippers	6	3.3 (0.8)	0.37	0.63 (0.20)
Tomato growers	2	1.5 (0.7)	0.20	0.80 (0.14)
Banks	24	3.9 (1.0)	0.49	0.51 (0.20)
Miscellaneous endusers	13	n/a	0.53	0.47 (0.17)
Total	89	3.1	0.44	0.56 (0.19)
Intermediaries				
Extension	38	5.5 (0.5)	0.60	0.40 (0.22)
In-house analysts	5	5.4 (0.6)	0.57	0.43 (0.11)
Miscellaneous intermediaries	3	5.3 (1.2)	0.52	0.48 (0.43)
Brokers	9	4.4 (0.09)	0.53	0.47 (0.26)
Commercial vendors	30	4.3 (1.3)	0.53	0.47 (0.25)
Commodity associations	23	4.1 (1.3)	0.47	0.53 (0.24)
Nonagricultural media	3	3.7 (1.2)	0.43	0.57 (0.21)
Agricultural media	19	3.5 (0.9)	0.30	0.70 (0.15)
Total	130	4.5 (1.0)	0.50	0.50 (0.21)

[a] 1 = some high school, 2 = high school, 3 = some college, 4 = college, 5 = some graduate school, and 6 = Ph.D.

of education. This difference is not significant when compared to those who have not completed high school, but it is when compared to those who have. Results indicate that participants in wheat (significantly) and potato markets use less data than do tomato growers. One possible explanation for this result is that tomatoes are highly perishable, markets clear quickly, and participants place high value on constantly updated price data. These findings support hypotheses H1 because actors with higher levels of human capital resources see data as more attractive than information.

Public vs. Private Information

Table 4 illustrates that public information is heavily relied upon, especially by intermediaries. Endusers use a significantly (0.01) higher percentage of privately provided information (70%) than do intermediaries (55%). Three complementary explanations can be considered. First, farmers and decision makers in agricultural businesses may be less analytically competent and, thus, choose to rely on specialized service providers. Second, intermediaries exist specifically to process raw or more general publicly generated information on behalf of agricultural businesses. Third, it is possible that public information providers design and produce information explicitly targeted to intermediaries rather than endusers. Note that whereas extension is treated as a class of intermediary, it must be recognized as an important public provider of information. Extension personnel report the heaviest use of public information. This may simply be because extension agents often exchange information among themselves and are heavily dependent on land-grant and USDA research.

Among endusers, farmers generally use less public information. Wheat farmers are an exception to this and report higher levels of public information use than do wheat elevators or exporters. This may be attributable to wheat's status as a major crop and USDA's historical commitment to producing considerable amounts of relevant information. Addi-

Table 4. Percent of Public vs. Private Information Inputs

	Obs.	% Public Information	% Private Information	SD
Endusers				
Wheat farmers	6	0.39	0.61	0.26
Wheat elevators	8	0.30	0.70	0.21
Wheat exporters	5	0.16	0.84	0.16
Potato grower/packer/shippers	7	0.30	0.70	0.19
Potato processors	5	0.28	0.72	0.41
Hog farmers	3	0.27	0.73	0.29
Hog processors	4	0.34	0.66	0.26
Hog input suppliers	2	0.45	0.55	0.21
Tomato growers	2	0.05	0.95	0.07
Tomato grower/packer/shippers	6	0.28	0.72	0.17
Tomato input suppliers	5	0.39	0.61	0.17
Banks	24	0.34	0.66	0.17
Miscellaneous endusers	13	0.38	0.62	0.33
Total	90	0.30	0.70	0.22
Intermediaries				
Brokers	9	0.34	0.66	0.32
Commodity associations	24	0.43	0.57	0.21
Agricultural media	19	0.43	0.57	0.18
Nonagricultural media	3	0.52	0.48	0.23
Commercial vendors	30	0.41	0.59	0.27
Extension/LGU	36	0.63	0.37	0.26
In-house analysts	5	0.29	0.71	0.16
Miscellaneous intermediaries	3	0.58	0.42	0.33
Total intermediaries	129	0.45	0.55	0.26

tionally, we note that use of public information by tomato growers is extremely low, perhaps as a function of its minor crop status and because production and marketing activities are concentrated in a small number of locations, each of which services its own information needs, generally through collective structures (i.e., commodity associations).

Two results stand out in table 3 with respect to public and private information. Individuals with graduate training and intermediaries are significantly much higher users of public information than are other types of respondents. This result suggests that public information is not targeted, translation requires a high degree of human capital, and it is a raw input for intermediaries (H3). The importance of human capital suggests that there may be significant barriers to access public information, and public information may not have "pure" public good properties. Although not overwhelmingly different from wheat and hogs, we note that tomato and potato commodity markets, which are small relative to wheat and hogs, do not feature heavy use of publicly supplied information.

Formal vs. Informal Information

Informal information is obviously of great importance, especially for endusers who report on average equal reliance on formal and informal information. As indicated in table 5, intermediaries use significantly (0.01) more formal information (72%) than do endusers (48%). Reliance of intermediaries on formal information reflects their functional role as professional analysts. By virtue of their deeply embedded position in communities and high levels of interpersonal and repeated interaction, endusers make more effective use of informal information. Among endusers, produce commodities (potatoes and tomatoes) appear to rely heavily on informal sources. Access to formal information within these commodity groups may be limited due to their small market size and the need for quick answers in rapidly clearing markets. In contrast, hog farmers seem to be relatively heavy users of formal information, perhaps because they have less flexibility in terms of production volume.

Generally, decision makers at the farm level tend to make much more use of informal information. As hypothesized in H3,

Table 5. Formal and Informal Information Use

	Obs.	% Formal	% Informal	SD
Endusers				
Wheat farmers	6	0.54	0.46	0.23
Wheat elevators	8	0.55	0.45	0.22
Wheat exporters	5	0.45	0.55	0.31
Potato grower/packer/shippers	7	0.26	0.74	0.16
Potato processors	5	0.36	0.64	0.13
Hog farmers	3	0.78	0.22	0.10
Hog processors	4	0.40	0.60	0.12
Hog input suppliers	2	0.40	0.60	0.28
Tomato growers	2	0.35	0.65	0.35
Tomato grower/packer/shippers	6	0.31	0.69	0.12
Tomato input suppliers	5	0.50	0.50	0.16
Banks	24	0.60	0.40	0.20
Miscellaneous endusers	13	0.68	0.32	0.26
Total	90	0.48	0.52	0.34
Intermediaries				
Brokers	9	0.79	0.21	0.13
Commodity associations	24	0.69	0.31	0.21
Agricultural media	19	0.77	0.23	0.21
Nonagricultural media	3	0.47	0.53	0.25
Commercial info. vendor	30	0.70	0.30	0.23
Extension	37	0.72	0.28	0.19
In-house analysts	4	0.78	0.22	0.16
Miscellaneous intermediaries	3	0.88	0.12	0.08
Total	129	0.72	0.28	0.18

table 3 shows that education is positively related to use of formal information. It appears that the educational threshold to access formal information is a high school diploma. However, the strongest effects are attributable to commodity and functional position in the commodity system. Those involved in potatoes seem to use significantly more informal information. This might be explained by the lack of formal information dealing with potatoes and an organizational structure in which small numbers of firms interact intensively in a local context. At the level of farm production, we can suggest that Washington potato producers bargain collectively for production contracts with a very small group of processors (90% of the region's potatoes are sold as frozen French fries) whereas California fresh tomato producers are engaged in an extremely competitive market. Most notably, intermediaries use significantly higher proportions of formal information than endusers illustrating that, within commodity systems, information service providers serve to process (i.e., interpret and reformat) formal information through application of their analytic capabilities.

Conclusion

We have modeled agricultural economic analytic services as production inputs. Our analysis focused on how agents' choices among differently formatted external decision support services reflect their analytic competencies and the nature of the uncertainty they face. Notably, human capital constraints shape actors' demand for specific types of information services. We find that actors with higher levels of human capital are more likely to make use of less-refined, less-finely targeted information. Thus, actors positioned to undertake analytic tasks use more raw data, more publicly provided information, and rely more frequently on formal information channels. In contrast, those who have lower levels of human capital use more heavily processed information and rely more intensively on commercial intermediaries and informal sources.

Our empirical analysis is based on reported behavior of respondents, who were asked to identify their current sources of agricultural economic information. Respondents' choice of service providers reflect their demand and preferences, but also constraints imposed by

available supply. For example, in the fresh tomato industry, a minor crop produced in only a few locations by a small number of firms, USDA is not a major provider of information services, and commercial providers generally do not exist. Detailed analysis of costs and benefits of service provision are required to understand the structure of localized information systems and assess the implications of redesign of public service provision. Moreover, to account for dynamics in information systems, historical and comparative analysis is needed.

Presently, there is tremendous interest in the institutional relations of research and extension and the role of knowledge in economic performance. In economic research, these questions are generally framed in terms of whether public and private sector investments are complements or substitutes (David, Hall, and Toole). The more macro-oriented studies of such complementarity treat knowledge and research output as a homogenous product. In contrast, we focus on heterogeneity of information formats. Our results demonstrate widespread, if variable, use of publicly provided information among most every class of organization engaged in agriculture, both firms engaged directly in production and those providing services. Usage is particularly intense among a diverse array of analytic service providers, who process data and information on behalf of agricultural businesses. These intermediaries provide more or less customized decision-support services, and this function is powerfully supported by low-cost, minimally processed public information. Although this finding of functional specialization suggests that the "public does wholesale and private does retail," such a linear characterization is incomplete as we see that frontline decision makers on farms and in agricultural input and output industries directly access public agency services. Further, private organizations produce and access significant amounts of information independent of government agencies. The empirical portrait of the division of labor we present suggests tremendous complexity and localized variability (Wolf, Just, and Zilberman, 2001). Future research on systems of information at the levels of firms, territories, sectors, or nations must account for heterogeneity of information itself in addition to differences among senders and receivers.

We have reframed the issue of public–private sector complementarity in terms of interaction among a broader set of agents engaged in the knowledge system. We have shown that the internal competencies of users of information services shape their engagement with external service providers. Results indicate that complementarity between senders and receivers rests largely on the distribution of human capital. Further understanding of the time constraints each individual faces would likely reveal a strong relationship between time spent in decision making and the types of decision support used. Firms engaged in agrofood commodity handling to varying degrees outsource their analytic requirements to more or less specialized consultants, who invest in people, equipment, and organizational routines so as to be able to produce decision-support services. At the same time, public agencies make use of these consultants to perform translation services of their aggregated and sometimes technical output. Thus, policy analysis focused on reorientation of public agencies engaged in research and extension and feasibility of entrepreneurial entry into information markets is a highly site-specific project. In addition to the theoretical project of incorporating actors' specific competencies into a valuation of information, our framework contributes to the general effort of redesigning information systems in step with agrofood system evolution. To contemplate institutional innovation within information systems at the sectoral, regional, or national level, a basic requirement is knowing who is serving whom and the principles governing bilateral exchange and systemic organization. Toward this end, our research has demonstrated how the distribution of analytic capabilities among individual participants is reflected in the social division of labor among the range of relevant public and private sector actors.

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