# ORGANIC FOOD AND SUSTAINABLE AGRICULTURE

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Organic farming pioneers began searching for farming methods that do not rely on synthetic chemicals. Some 10 or 20 years ago, few believed that producers of organic products could survive economically. In 1970, Rodale Press in Pennsylvania began a program to certify organic food and, in 1971, published a list of 34 organic farms in California. Some of these farmers established the California Organic Growers. In 1973, 50 farmers reorganized this organization into the California Certified Organic Farmers (CCOF). By 1988, the CCOF had 380 growers, and it continues to expand rapidly. Cook (1988) estimates that in 1987, approximately 900 farmers of organic products were operating in California—about 1 percent of the industry total of 82,463 (1982 Census of Agriculture). They accounted for farmgate revenue of $50 million from 30,000 acres in California, relative to 7,831,307 total acres farmed in the state. This represents significant growth since 1982, when Altieri et al. (1983) estimated that 273 farmers of organic products were in operation.

Despite little support beyond their own organizations, such farmers have successfully devised complex strategies to grow and market organic food and have survived for more than a decade. Their survival is noteworthy given the comparable institutional superstructure supporting the research, development, registration, certification, and application of synthetic chemicals. Partially in response to the needs of organic farmers, the University of California in 1986 established the Sustainable Agriculture Research and Education Program (SAREP). Other states have developed similar programs, and in fiscal-year 1988 a national program—now called Low-Input Sustainable Agriculture (LISA)—was initiated.

Section II summarizes the scientific debate over the hazards of synthetic chemicals, describes key elements of current command and control policies and of institutions to directly internalize the negative externalities from using synthetic chemicals, and highlights the externalities that remain. Section III defines the terms "organic," "integrated pest management" (IPM), "low input," and "sustainable agriculture" in the context of the evolution of institutions and policies to indirectly internalize negative externalities through economic incentives. Section IV presents new research and a literature review leading to two conclusions: (i) the market for organic food presently is in disequilibrium and is inefficient, and (ii) small perturbations in market demand and supply have the potential to supplant a significant share of conventional food with organic food. Section V presents three groups of policy proposals to reduce negative externalities indirectly. First are policies to improve the efficiency of the market for organic food. Second are changes in policies to remove incentives favoring conventional agriculture over low-input agriculture. Third are policies to establish incentives promoting a fair competition between conventional agriculture and low-input agriculture, whereby social costs and returns—not private costs and returns—are the basis for comparison.

## II. REGULATION AND DELETERIOUS EFFECTS OF AGRICULTURAL CHEMICALS

This section summarizes the debate over the evidence of negative externalities from using of synthetic chemicals. It begins with the evidence documenting externalities and follows that with the counter evidence. It then discusses the institutions, reviews criticisms of current regulatory programs' command and control approach, and discusses externalities remaining under present regulation.

### A. *The Debate*

Rancorous controversy surrounds the issue of the level of risk that agricultural chemicals pose to human health and the environment. A catalog of alleged negative externalities includes the greenhouse effect caused partly by nitrous oxides from fertilizer (Firor and Portney, 1982); acute and chronic adverse health effects to farm workers and their families through residue on clothing (Coye, 1986); the persistence and ubiquitousness of pesticides and breakdown products in groundwater and surface water (Hallberg, 1987; Holden, 1986; Pye et al., 1983; U.S. Congress OTA, 1984); possible residue of pesticides and breakdown products on food (Natural Research Council, 1987); bioaccumulation in food chains resulting in contaminated fish from lakes, rivers, streams, and oceans, as well as destruction and poisoning of birds and other wildlife (Papendick et al., 1986; Carson, 1962); increasing resistance of pests to pesticides (Hueth and Regev, 1974; National Research Council, 1986); pest resurgence and secondary outbreaks affecting neighboring farms (Flint and Van den Bosch, 1981); and massive soil erosion, often linked to monoculture production of corn, soybeans, and other cash crops on fragile soils (Sampson, 1985).

Perhaps the most worrisome evidence to date concerns adverse health effects both to farm workers and to consumers of contaminated drinking water. Examples of the growing body of evidence include a study of farm workers (Wasserstrom and Wiles, 1985) and a 20-year study of more than 1,000 agricultural counties (Stokes and Brace, 1988) reporting a strong correlation between the amounts of certain pesticides and death rates due to cancer. A recent study of 12 California counties high in pesticide use (Schwartz, 1988) found that the risk of bearing a child with a limb reduction defect was 1.9 times that of the population average.

On the other hand, Ames et al. (1987) report that smoking, high fat consumption, naturally occurring carcinogens, aflatoxin in peanut butter, nitrites and nitrates in bacon and other cured meat, charred meat and fish from barbecues, and other common substances consumed voluntarily are much more potent carcinogens than are pesticide residues consumed involuntarily from food or water. These authors caution that plant breeding programs to develop natural resistance to pests may increase the risk of cancer even more than does the continuing use of synthetic pesticides. Their economic and public policy analysis concludes that "the levels of synthetic pollutants in drinking water and of synthetic pesticide residues in foods...is a minimal carcinogenic hazard relative to the background of natural carcinogens. ...We do need to work out some balance between chemophobia with its high costs to the national wealth, and sensible management of industrial chemicals." The evidence that section IV presents, however, counters fears of "high costs to the national wealth" resulting from minimizing chemical use.

Concurring with Ames et al., Winter (1988) reports that "the U.S. Food and Drug Administration (FDA) considers pesticide residues in foods as only their fifth priority [following] "microbial contamination, nutritional imbalance, environmental contaminants and naturally occurring toxins." Moreover, the California Department of Food and Agriculture's (CDFA) 1987 evaluation of more than 7,000 samples revealed that only 0.3 percent of conventionally grown food had detectable residues above the legal tolerance, which usually is set 100 times below the level expected to cause harm. Criticisms have been directed at the testing procedures and standards at the state (Price, 1988) and federal (Mott, 1987) levels. Given the limitations of science to prove or disprove either side of the issue, the controversy likely will continue. The difficulties facing science exacerbate the problems of forming public policy.

### B. *Issues Posed by Current Regulatory Policies and Programs*

Growing political forces resulted in passage of the Federal Environmental Pesticide Control Act, a 1972 amendment to the 1947 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The FIFRA empowers the EPA to register, regulate, label, and certify the use and application of pesticides. Other federal and state agencies also hold regulatory authority.[1] The command and control philosophy of the FIFRA has high administrative costs and sometimes fails to advance the objective of reducing risk to human health and the environment. Two reasons for this are the nonpoint nature of the problem and the discrete, rather than continuous, policy options that the FIFRA affords. The regulatory options are either to permit using a chemical on a particular crop in some region or to ban the chemical for that particular use. These discrete options contrast with a policy based on economic incentives resulting in reduction of the amount used to some level between the present level and zero. To a certain extent, however, the level consumed as residue on food can be reduced by banning use on some crops—or just in some regions—but permitting use of the same chemical in other instances. The nonpoint aspect of the problem is that the pollution source is spread over entire regions and that the pathways to exposure are numerous—e.g., groundwater, surface water runoff, air drift, soil, residue on the crop, residue on crop trash—and this results in a complex connection to the specific types of damage cited above. Because of the dispersed pattern of pesticide use, compliance with regulations is difficult to enforce and so violations are common (Gips, 1987).

Because of the nonpoint nature of the problem and the discrete choice inherent in command and control, the EPA and state regulatory agencies can succeed only partially in internalizing negative externalities directly. To balance the benefits with the costs of using synthetic chemicals in an economically efficient manner, suspension or cancellation proceedings ideally should include a coordinated assessment of the change in crop mix and production methods that likely would occur in every state, the location of crops near environmentally sensitive areas, the amount of runoff and drift, all breakdown products and their half-lives, routes to groundwater, the exposure rate, acute and chronic toxic effects at the exposure level, the exposure routes for all substitutes, the old and new exposure levels for the substitutes, the adverse health effects at the old and new exposure levels, etc. The fact remains that the adverse health effects at any exposure level are disputed and require inference from animal studies for effects on humans, though such studies use sample sizes too small to measure statistically discernable differences between exposed groups and control groups at the relevant dosage levels.[2] Because of the sample size problem, animals are exposed to dosage rates substantially higher than comparable dosages to which humans are exposed. Scientific ignorance is legion, even when assessment data are available. A major weakness of command and control regulation is that reliable information is unavailable or expensive.

For consumers, negative externalities occur for three reasons. First, labels fail to include accurate and complete information about the amounts of pesticide residue and breakdown products on food. Second, because health scientists disagree on the risk resulting from exposure to synthetic chemicals, one could hardly expect consumers to evaluate the information knowledgeably even if the information were available. Third, food is not available along a continuum of differing levels of residues at differing costs and prices. The result is an economically inefficient level of market provision of public health associated with the risk of pesticide residues.

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[1] The Food and Drug Administration (FDA) has the responsibility to establish, monitor, and enforce tolerances of pesticide residues on fish. The U.S. Department of Agriculture and the FDA assist the EPA in monitoring residues in food. The Occupational Health and Safety Administration shares some authority with the EPA for protecting agricultural workers.

[2] The problem of sample size at low doses is endemic to dose–response studies. Usually a threshold is assumed or the functional form determines the size of the estimate in the tail of the distribution. The same problem occurs in econometric studies where the choice is between a probit or a logit specification. For example, if a small dose actually causes mortality in an extremely small fraction of the population, then one would need an exceedingly large sample size for the experiment to reveal a statistically discernable difference. The problem is serious, however, since an extremely small fraction of a population of hundreds of millions can mean a substantial number of deaths.

For farm workers, negative externalities continue to occur for two reasons. First, implementing the safety regulations designed to internalize the externalities requires literacy and the farmer's active participation, both of which frequently are missing. Second, no evidence exists that the wage rate of the worker includes a risk premium. For the single worker, the appropriate test would be to determine whether equivalent workers are paid the same regardless of whether they work in an organic field or in a conventional field with chemical residue. The literature apparently includes no model incorporating the worker's family—including children with birth defects—into the risk premium. One would have to observe compensation among family members to support the hypothesis that the worker's wage premium for risk also accounts for increased risk to family members.

Three types of policies would internalize these externalities to farm workers and their families. Enforcing safety regulations and worker education are two policies currently in favor. Enforcement includes inspection and fines, and worker education can include on-the-job activities as well as safety in the home—e.g., safe handling of contaminated clothing. But these policies are expensive and, given budget constraints, federal and state agencies write regulations shifting the cost to the producer, who has a monetary incentive to avoid active participation and concomitant costs. Moreover, inspections and worker education programs may easily miss migrant workers, who sometimes sleep in the fields and have little or no access to basic sanitation—much less washing machines. The solution to worker safety externalities cannot be found in torts and property rights, for several reasons. Workers are migrants. Some are working illegally, and exposure is both direct and indirect—through water and contaminated clothes. The number of active ingredients and breakdown products precludes proof of cause and effect. Worker migration limits identification of a responsible party.

## III. ETYMOLOGY AND INSTITUTIONAL EVOLUTION

This section defines the terms organic, sustainable, IPM, and low-input technologies. Organic refers to a class of commodity in the context of consumer choice when defined in reference to growing practices. Sustainable, low-input, and IPM refer to systems of production on the farm. While defining these terms, the discussion here presents some details about aspects of the agroecosystem, which is referred to as human capital. This perspective will aid the reader in the discussion of market disequilibrium in section IV and in the discussion of federal and state research programs in this section.

Organic is now written into California law, and Congress has introduced legislation for a federal definition. Proposed federal and existing state laws define conditions for labelling food organic. This term as used here refers to a clearly labelled commodity with particular characteristics relating to conditions under which the food is produced, similar to the situation with other goods, such as USDA categories of beef.

For sustainable and low-input agricultural technologies, substituting both human capital and labor for chemicals occurs in the following context. These agricultural technologies have in common an underlying philosophy of how to focus on the agroecosystem: as an integrated, interdependent, evolutionary, and interactive system. Knowledge of the system requires investing in human capital. Applying the knowledge requires labor-intensive monitoring of the stage of developing crops and weeds, soil, pests, predators, parasites, moisture, temperature, and other variables of the agroecosystem.

### A. *Integrated Pest Management*

During the late 1950s, several entomologists (Stern et al., 1959) became concerned that the use of pesticides in conventional agriculture was leading to a pesticide treadmill: Increasingly larger doses and increasing numbers of applications were required due to increasing pest resistance, resurgence, and secondary outbreaks. Broad-spectrum pesticides killed not only the pest but also predators and parasites, called beneficial insects since they are natural enemies of pests and potential pests. The pest population, now unchecked by their natural enemies, resurged in ever greater numbers. This required further applications. Moreover, other insects previously controlled by their natural enemies—and consequently referred to as secondary pests—also increased unchecked, and this required pesticide applications to control secondary outbreaks. Entomologists defined the concept of integrated control as "pest control which combines and integrates biological and chemical control" (Stern et al., 1959, p. 86) where pesticide application is to be "based on conclusions reached from periodically measured population densities of pests and beneficial species...and based on a sound knowledge of the ecology of the organisms involved and projected future population trends of pests and natural enemies" (Stern et al., 1959, p. 87). The concept of integrated control subsequently was broadened to include all control methods (Smith et al., 1976) and formally was renamed integrated pest management by the President's Council on Environmental Quality (1971).

### B. *Organic Foods*

The emphasis here on organic food relative to other low-input methods is that organic production systems are closer than other low-input methods to the definition of a sustainable system given below. Organic products are defined by California law in H&S Code, Section 26569.11. Foods sold as grown organically shall not use "synthetically compounded fertilizers, pesticides, or growth regulators." As a practical matter, enforcing the law is up to private industry. For the California Certified Organic Farmers to certify agricultural products as organic, three requirements must be met: (i) no synthetic chemicals may be used, (ii) a long-term program of soil management is required so as to enhance biological activity and minimize the use of soluble nutrient amendments, and (iii) the farmer must agree to a certification process including recordkeeping, inspections, laboratory testing, and a one-year probation period for chemical residue in soils to dissipate at least partially. In this context, organic farming has a meaning beyond the context of marketing, as it extends to the farming practices.

A proposed federal counterpart is the Farm Conservation and Water Protection Act of 1988. This act would require the Secretary of Agriculture to "establish and carry out a program to provide for the official certification and labeling of agricultural commodities and products that were produced using organic practices."

### C. *Institutional Evolution*

The etymology of the terms organic, IPM, sustainable, and low-input agriculture derive partly from policies designed to initiate publicly supported research of both sustainable farming and IPM practices. Current levels of tax-supported efforts are minuscule relative to support of conventional agriculture, but the trend is promising. From 1972 to 1978, the National Science Foundation, the EPA, and the USDA funded a \$5.5 million, 18-university research project referred to as the Huffaker Project (after the director) so as to develop IPM (see Bottrell, 1979, and references therein). The Huffaker Project was continued with the Adkisson Project, which was a multimillion-dollar and multiuniversity project of the early 1980s that reported successful IPM programs for cotton, alfalfa, soybeans, grapes, and apples (Frisbie and Adkisson, 1985).

An example of programs begun by individual states is the University of California Sustainable Agriculture Research and Education Program, established in 1986 at the behest of the California legislature. The goals of the program are to focus existing scientific information and to support new research. The program funded 19 projects in 1988 with a total of \$250,000.

At the federal level, Congress created a program—in Subtitle C of the Food Security Act of 1985 (PL 99-198)—for research and extension of low-input and sustainable farming methods. In December 1987, Congress appropriated \$3.9 million for this program, now referred to as the Low-Input Sustainable Agriculture program. In fiscal-year 1989, Congress appropriated \$4.45 million for this program (Madden, 1988).

One can find common themes in the LISA and the SAREP. Both fund projects outside the traditional land-grant universities. Both emphasize systems approaches that usually require interdisciplinary research. Both encourage research projects with cooperation between university researchers and farmers. Both include studying externalities from conventional agriculture as part of an overall comparison between conventional and sustainable agriculture. And both emphasize demonstrating economic viability (Auburn, 1988; Madden, 1987, 1988).

### D. *Low-Input and Sustainable Agriculture*

The phrase low-input encompasses IPM, as well as substituting legumes for fertilizer and herbicides, low tillage methods, and organic farming. The SAREP describes sustainable agriculture as "one that combines successful economics with stewardship of natural and human resources for the immediate and long-term future." The addition of the word Sustainable to the title of the LISA program—originally termed Low-Input—is indicative of a goal met partially by IPM and other low-input methods. No definition of sustainable is rigorous or easy to put into operation.

In the literature on economic development, economists have begun grappling with a definition of sustainable.[3] Pezzey (1989) defined sustainable development as economic growth that can maintain utility from one generation to the next. This definition has two central aspects—production and utility—developed further below.

d'Arge et al. (1982) observed that discounted world gross product from more than a century into the future is virtually zero, so that profit-maximizing choices that could destroy the basis for survival can be optimal if the consequences don't occur until much later. Ecological systems provide renewable and nonrenewable amenities and inputs that the economic system uses in production and consumption. The economic system, in turn, produces outputs for consumption and waste returned to the environment. Waste products can affect the evolution and stability of ecological systems by reducing the flow of amenities and renewable inputs. In this context, one could define sustainable agriculture in terms of achieving a goal: developing an agricultural technology that can be continued from one generation to the next without altering ecosystems in a manner that reduces the flow of renewable inputs and without relying on nonrenewable inputs that—according to economic theory—increase in price faster than inflation.

Maintaining utility from one generation to the next is broader than maintaining the flow of renewable inputs. The environment provides not only a flow of inputs but also a flow of amenities for direct consumption, so that sustainable agriculture maintains the flow of environmental amenities. How the economic system of production is organized affects the utility derived from work. Farm size, farm ownership, exposure to chemicals in the workplace, and the environment for rural living are part of this broader definition.

Those concerned over conserving nonrenewable fossil fuels define sustainable agriculture narrowly as the substitution of knowledge (human capital) and information (labor: monitoring the agroecosystem) for petroleum-based inputs. As Barnett and Morse (1963) argued, technological change and

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[3] Since the first draft of this paper, several important papers have developed and refined the concept of sustainable (see Barbier, 1989; Barbier and Markandya, forthcoming; Conway and Barbier, 1988; Pearce, Barbier, and Markandya, 1988). Time constraints precluded incorporating these contributions into this paper.

substitution have kept prices of agricultural commodities from increasing. This result was confirmed by Hall and Hall (1984). Given the increases in prices of petroleum products (Hall and Hall, 1984), developing and adopting sustainable agriculture represents a continuation of this process from the very narrow perspective of private costs.

To maintain the flow of renewable resources from ecosystems, sustainable agriculture has the goal of avoiding short-sightedness. In the tropics, this goal includes avoiding the consequences of slash-and-burn agriculture such as laterization of soil and reduction of biodiversity (Norgaard, 1987). This goal also includes reducing emissions of nitrogen gases from fertilizers by planting nitrogen-fixing legumes, reducing soil erosion from conventional agricultural practices, and avoiding ever-increasing doses of pesticides due to pest resurgence, secondary outbreaks, and increasing resistance.

Sustainable is a broader term than is organic. Yet when one considers IPM, other low-input practices, and organic farming, one finds that even the best current practices contribute to the greenhouse effect by emitting carbon dioxide from energy use—directly from farm machinery and indirectly from energy used to pump water. Legumes fix nitrogen and thereby avoid a greenhouse effect, but organic farming includes applying manure that emits nitrogen gas—as does synthetic fertilizer (Firor, 1982, p. 187)—and thus adds to the greenhouse effect. Because the greenhouse effect is expected to have major consequences for agricultural production, these low-input practices are not sustainable in the strict sense defined above.

Totally eliminating externalities *per se* is not the central focus of sustainable agriculture. Some external costs may well be sustainable. Similarly, developing and adopting low-input agriculture will reduce negative externalities substantially, but low-input agriculture is not designed to internalize all externalities.

## IV. MARKET INEFFICIENCY AND GROWTH

This section presents new research supporting the conclusion that opportunities exist for substantial growth in markets for organic products, that the market for organic food currently is in disequilibrium,[4] and that the market for organic products is inefficient due to this disequilibrium and to the current market's small size. The analysis first focuses on producers, then on consumers, and then on market volume and prices. Finally, this section summarizes the evidence that the market for organic food is inefficient.

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[4] The concept of equilibrium has two conditions. First, once a system is in equilibrium, it tends to remain there in the absence of exogenous shocks. Second, a system tends toward equilibrium if not there. If either of these two conditions is absent, a system is in disequilibrium. Manifestations of a market system in disequilibrium include intermittent availability of a product, latent demand adduced by market surveys, entry into or exit from an industry, and fluctuations in prices and volume.

### A. *Producers*

During the early stages of organic farming—i.e., during the past decade—many farmers participated due to nonpecuniary rewards related to lifestyle and beliefs. Large-scale farmers' adopting organic farming now results more from profit motives. Acreage in organic production is expanding rapidly. So are total sales, so as to support the conclusion of disequilibrium. A literature review, the authors' own econometric analyses, and a controlled experiment compare yields and costs of conventional agriculture with food and fiber grown without synthetic chemicals. The authors find much smaller differences than were believed previously. This evidence belies fears of a large economic loss from agriculture in the absence of chemical inputs. Implementing low-input agricultural practices can require extensive knowledge of agroecosystems. This knowledge requires a substantial investment in human capital that may tend to delay such adoption and maintain for some time the short-run higher-than-normal return to management of agroecosystems.

In connection with a joint effort by the SAREP and the Organic Market News and Information Service (OMNIS), Cook (1988) surveyed organic producers in California so as to obtain basic descriptive data on industry size, commodities grown, acreage, and growers' perceptions of obstacles limiting expansion.[5] Those exclusively organic farms were earlier adopters and tend to be smaller and less concerned over profitability as a motive. A significant percentage of organic growers operate diversified farms. Some are in transition from conventional agricultural practices and some are strictly organic producers but with only part of their land certified by the CCOF.[6] The newest entrants to organic farming have larger operations than had earlier organic farms. The new entrants mirror more closely conventional agriculture in size and have stated their motive: perceived potential profit.

Crosson and Ekey (1987) surveyed and assessed more than 30 articles, reports, and books on organic agriculture. They summarized that organic agriculture results in lower yield and net revenue per acre and in higher labor and lower input costs, but some evidence exists for higher prices for organic

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[5] The population of organic producers was identified from the 1987 list of 284 CCOF growers and by soliciting the names of suppliers to distributors of organic commodities, names compiled by the California Department of Food and Agriculture (CDFA), and names of those who attended organic farmer conferences. The mail survey was sent to a total of 738 organic producers in California. The response rate was 44 percent.

[6] The average farm size of respondents was 58 acres with a statewide average of 38 acres in organic commodities, compared with a 390-acre average reported in the 1982 census. Excluding the six largest growers in the sample, the average size is 27 acres in organic production. The concentration of farm size for organic commodities mirrors conventional agriculture in California in that 2 percent of the respondents represent 40 percent of the total reported acreage. The largest 5 percent of the organic farms were responsible for 80 percent of the total volume of sales. This reveals somewhat greater concentration than does conventional agriculture. Revenue for respondents averaged $117,566 in 1987, compared with a 1982 census average of $151,479. The eight largest respondents averaged $1,777,144 while the remainder averaged $24,723.

food (Crosson and Ekey, 1987, p. 15). Cook's (1987) literature review found similar results. The strawman of an immediate and total ban on agricultural chemicals was the focus of studies by Olson et al. (1982), the Council for Agricultural Science and Technology (1980), and Langley et al. (1983) predicting that extensive damage to yield would result. These predictions erroneously referenced organic farming but are based on estimates of yield and costs of farming methods similar to those of the 1940s. Crosson and Ekey concluded that these studies are not compatible with available evidence. (See, for example, Oelhaf, 1978; and Klepper et al., 1977.)

The first econometric evaluation of farming without chemicals in California (Hall, 1983) was based on five years of panel data collected from San Joaquin Valley cotton and citrus farmers during the 1970s. The sample included farmers who chose to farm without chemicals. Hall (1977a, 1983) and Hall and Duncan (1984)[7] contain detailed discussion of the sample design, non-response bias, stratification and clusters, self-selection bias, and choice-based sampling bias for this data set. The conclusion is that the impact of chemicals on yield is much smaller than previous estimates had indicated. (For example, see California Department of Food and Agriculture, Environmental Assessment Team, 1979.) For alternative functional forms, the point estimates of percentage change in yield due to chemicals vary from –6 to +14 percent for cotton and from –17 to +24 percent for citrus. Of course, farming without chemicals reduces material and application costs for fertilizers, herbicides, insecticides, and miticides. After one accounts for cost reductions, the point estimates of the percentage change in gross revenue from chemicals vary, depending on the functional form, from –22 to –3 percent for cotton and from –32 to +7 percent for citrus. The point estimates indicate that organic agriculture may be more profitable, but the interval estimates span a range larger than the variability in point estimates presented above. This makes the conclusion uncertain.

Hall (1988), using data from a controlled experiment in alfalfa, combined a damage function, a model of the pest population, and a decision rule for the agricultural experiment station. The decision rule determines the pest population threshold—recommended by the agricultural extension service—that should be exceeded before applying insecticide in an IPM program. The estimated parameters resulted in the prediction that if no insecticide were applied, then the Egyptian Alfalfa Weevil (EAW) would destroy 8.9 percent of the crop. Given alfalfa prices at $125 per ton, this would imply a revenue loss of about $60 per acre. Conventional practices typically include $25 to $35 per acre in insecticide material and application costs, multiplied by an average of two to three applications per season. Thus, refraining from applying insecticide appears competitive with conventional practices. However, prices have varied considerably, and this is an important caveat in these calculations.[8]

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[7] The estimation procedures in Hall (1983) address the issues of simultaneous equations bias and specifications error due to choice of functional form, omission of variables, inclusion of improper variables, and managerial ability.

### B. *Consumers*

The authors' research concludes that some consumers are willing to pay a premium for organic food, most consumers purchase food so labeled, and most consumers would be willing to buy more were it available. Evidence indicates that the main consumer constraint to greater purchases is lack of availability, which in turn indicates disequilibrium in the organic food market.

Jolly (1988) surveyed consumers so as to ascertain practices, beliefs, and potential for future consumption of organic food.[9] Consumers rate food safety, nutrition, healthfulness, and quality as the most important characteristics affecting food purchases. Food cost emerges as relatively less significant even though the sample had a wide spectrum of income distribution. Moreover, most respondents report that foods' flavor and healthfulness were declining over time. Specifically, consumers are most concerned about pesticide residues in food (62 percent concerned, 24 percent somewhat concerned) and then irradiation (60 and 19 percent, respectively). The level of concern over other health factors was lower: fat (52 and 29 percent), additives and preservatives (45 and 31 percent), salt (44 and 32 percent), cholesterol (43 and 34 percent), sugar (41 and 32 percent), fiber (36 and 37 percent), and artificial coloring (34 and 27 percent).

About half of those sampled responded that they had purchased organic fruits and vegetables within the preceding three months. About 18 percent had purchased organic chicken and eggs, 7.6 percent had purchased organic beef, and 3.2 percent had purchased organic pork. Only 15 percent of the respondents reported that they never had purchased organic food, 35 percent had purchased organic food in the past but had no plans to do so in the coming month, about 30 percent planned to purchase some organic food in the coming month, and 23 percent claimed that they shop regularly for organic food. Respondents rated the quality of organic food as follows: better—39 percent, the same—24 percent, worse—5 percent, don't know—

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[8] See Hall and Norgaard (1973) for a definition of the economic threshold. The EAW is the key pest since pesticide applications to control the EAW result in destruction of beneficial insects such as the convergent lady beetle and green lacewings. This results both in secondary outbreaks of lepidopterous, mite, and aphid pests and in the ensuing need for additional pesticide. To avoid secondary outbreaks, an IPM program was developed to determine the optimal application of pesticide in the late fall—rather than the spring—so as to avoid disrupting the beneficial insects.

[9] During fall 1987, 1,950 randomly selected households in Marin, Sacramento, and San Diego counties were surveyed by mail. The response rate was 54 percent. Some socioeconomic groups were not represented proportionately, but the sample is fairly representative of the counties from which they were drawn.

29 percent. The predominant constraints prohibiting greater purchases, according to respondents, were availability in the supermarkets where they shop, location of stores, and search time. Price was the second most important constraint on consumption but was less significant for consumers with higher incomes.

### C. *Volatile Prices and Market Disequilibrium*

Three sources of evidence point to an organic food market in disequilibrium: producers, consumers, and the operation of the market. In the survey by Jolly (1988), consumers reported that lack of availability was the single greatest impediment to increased consumption of organic food. Cook (1988) and Baker (1988) found rapidly expanding acreage in production of organic food. Cook found that the typical organic producer's farm size is growing and that new producers express a motive of profit maximization. This compares with early producers, who adhered to a particular lifestyle. Cook (1988) and Katz et al. (1988) found rapidly expanding sales. In econometric analyses and a controlled experiment, Hall (1983, 1988) found little difference in profit among conventional, organic, and other low-input practices. This portends substantial potential supply for modest price premiums of organic food. However, the perception that anything new is riskier works against transforming efficiently from conventional agriculture to low-input agriculture.[10]

Katz et al. (1988) analyzed prices of organic produce collected through the OMNIS.[11] Total reported wholesale value grew from $5.4 million to $7.6 million between 1986 and 1987, a 41 percent increase. Franco (1988) estimated that the OMNIS reported 40 to 50 percent of the volume of organic produce sold through wholesale distributors. Franco, relying on Cook's estimate (1988) that the wholesale distributors' share of total sales equals 28 percent, estimated the wholesale value at between $54 million and $69 million for the organic produce market in California during 1987.

Franco (1988) examined premiums paid for organic broccoli relative to prices paid for conventionally grown broccoli and examined the gap between prices paid to farmers and wholesale prices. Wholesale prices for organic broccoli vary less than do those for conventionally grown broccoli, yet the organic premium varied by a substantial amount—evidence of a thin market in disequilibrium. A large variable gap exists between prices paid to farmers and wholesale prices. This suggests opportunities for food brokers to reap positive economic profits.

The OMNIS has been reporting prices for only three years. Those market data, analyzed by Katz and Franco (1989), found erratic price behavior over the three years—evidence of an inefficient market. Franco (1989) found that, in the case study of broccoli prices, wholesale prices remained relatively constant from 1986 to 1987 while volume grew by 50 percent. This indicates an increase in the quantity supplied rather than a shift in demand, given Jolly's (1988) findings of high consumer interest: The demand has existed but the market has failed to provide consumers with the option. This conclusion is supported further by the extreme volatility of weekly volume and Franco's (1989) reports of undersupply. Cook (1988) found that from the perspective of retailers and distributors, the main obstacle is the difficulty of securing a steady volume of standard quality.

Prior to the Alar scare in March 1989, two supermarket chains in Northern California and two in Southern California marketed chemical-free food. This is a new trend also reported in other areas of the country. An important role of markets is providing information about the product characteristics and prices. Yet chemical-free food remains undefined. Attracting customers is crucial to the success of supermarket chains—especially during this current period of intense competition—and supermarkets are exploiting consumer interest in organic food as a marketing strategy. Full-page advertisements in the *Los Angeles Times* offered apples and apple products grown without Alar. By the time the Alar scare occurred, few farmers were applying the chemical. Because it is a systemic substance, however, Alar is present in the wood of the tree. This results in continued residues in the fruit for several years following the last dosage. This fact may explain partially the result of a survey paid for by the *Los Angeles Times* in April 1989, which reported the presence of Alar in apples advertised as chemical free. The increasingly prevalent use of "chemical free" as a marketing strategy is another indicator of latent consumer demand for food without residues. This provides further evidence of market demand for an unavailable product.

The evidence above is descriptive of a thin, infant market undergoing rapid transition. One key question is to what extent the market can expand before it reaches long-run equilibrium. A second key question is what the

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[10] The production of organic food requires adopting new technology—more sustainable production practices. The transition from conventional agriculture to low-input agriculture poses a temporary risk, whether such risk is real or perceived incorrectly (Dabbert and Madden, 1986). The intensive knowledge often required to implement more sustainable agricultural practices requires a substantial investment in human capital, the lack of which may pose a risk to those attempting to make the transition. Agricultural consulting firms provide managerial input and thus reduce the risks of such adoption. Empirical estimates of the economic risk of adopting IPM, as practiced by pest management consulting firms independent of chemical companies, show risks lower than those for conventional agriculture (Hall, 1977a,b, 1978, 1983). This is due primarily to decreased variability in yields and costs. The reduction in cost variability follows from the reduction in overall application of insecticides and miticides. Regarding the reduction in yield variability, note that IPM is an information technology. As such, the grower has updated information about the state of the agroecosystem, and this allows fine tuning regarding the timing of irrigation, pest control, and other practices. Because sustainable agricultural practices other than insect management are information intensive, one might expect this result to apply also to such other practices.

[11] The OMNIS was started by a joint venture of the CCOF and the Steering Committee for Sustainable Agriculture (SCSA) in 1984, and the first published report was in 1985 (Auburn, 1985, 1986). Selected distributors have been providing weekly reports on volume, grower and wholesale prices, and indications of over- and undersupply for more than 100 organically grown commodities.

characteristics of a developed market will be. An unknown distribution exists across consumers as to the premium that consumers are willing to pay for food without chemical residue. Some consumers are willing to pay a higher premium, some a lower premium, and some no premium. The extent to which marketing strategies can identify these consumers, increase such consumers' numbers through advertising, and extract the consumer surplus represents an opportunity for supermarkets to profit from providing organic food.

Sustainable food production requires new agricultural practices: crops grown without farm worker exposure, without fouling water supplies in rural communities, and without the other negative externalities already discussed. Organic farmers already are practicing many of these methods. Disequilibrium in organic food markets presents policy alternatives to reduce these externalities indirectly rather than directly. This is a form of economic jujitsu, or using the market to diminish the extent of market failure by reducing negative externalities.

## V. POLICY PRESCRIPTIONS

The analysis here emphasizes the distinctions between policies designed to improve efficiency in the market for organic food and those designed to remedy negative externalities associated with conventional agriculture through continuing adoption of more sustainable agricultural practices. An inefficient level of consumer health is a private good problem solved partially by consumers' having the choice to pay more for food with reduced levels of pesticide residues. But farm worker exposure, rural water contamination, and environmental damage are negative externality problems not solved entirely through an efficient market for organic food. However, as the production of organic food results in adopting more sustainable agricultural practices, negative externalities are reduced as the organic food market expands.

This section begins with three proposed policies that could improve the efficiency of the organic food market and then argues for policy changes to eliminate incentives favoring conventional agriculture over low-input agriculture. Finally, the policy prescription here is to level the playing field by using social costs and returns—not private costs and returns—as the basis for competition between conventional agriculture and low-input agriculture.

### A. *Policies for a More Efficient Market for Organic Food*

Inefficiencies in the organic food market exist in two dimensions: (i) the provision of consumer health and (ii) the disequilibrium associated with thin, infant markets. The authors prescribe three directly related policies to improve efficiency of the market for organic food as it expands toward long-run equilibrium.

For the market to provide an efficient level of consumer health, the theoretical solution requires fully informed consumers and available food identified correctly and clearly as free from chemical residues. But the costs of residue detection depend partially on the instruments and procedures for testing, and some residues simply cannot be detected at any cost. As a practical matter, the problem is solved partially by the availability in supermarkets of food grown without synthetic chemicals and, secondarily, by consumers' having better information of measured residue levels and of growing practices that result in chemical residues.

One proposal is for research on the potential profit from supermarkets' marketing strategies. This research could identify profitable promotional campaigns that justify supermarkets' decisions to increase availability and consumer awareness and to affect consumer preferences. Researchers could accomplish this proposal with interested pioneers in the supermarket industry in a manner expanding low-input agriculture through derived demand. USDA and land-grant universities with agricultural extension services traditionally engage in marketing research. The small fraction of those funds focused on the organic food market could be increased. Other potential funding agencies include state programs such as the SAREP and the Leopold Center in Iowa, the federal LISA program, and the EPA.

A second proposal is to enhance the organic food market through expanding market information such as that provided by the OMNIS. A market information service could provide information on current prices, availability, distributors, wholesalers, and producers. This could allow the market to expand more rapidly. The logical organization to perform this service is the Federal State Market News Information Service, which performs a similar service for conventionally grown commodities.

As a third proposal, legal definitions of alternative labels—e.g., organic, CCOF certified, IPM, chemical free—would aid consumer decisions and thereby reduce information costs to society and increase the efficiency of the market for organic food. Supermarket chains, with no interference from the legislature, could enter into advertising campaigns to educate consumers about the differences among organic, CCOF certified, and chemical free. Chemical-free food does not necessarily mean organically grown as defined by California law or as required by food with a CCOF label. Chemical free, as advertised by three California supermarket chains, sometimes means food certified by an independent laboratory to achieve a certain pesticide residue standard—irrespective of the grower's pest control practices. At other times, chemical free refers to a supermarket supplier's claims that the product was grown without some particular chemical or chemicals. In neither case does any penalty seem to exist for false advertising.[12] Even if supermarkets tested

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[12] In April 1989, the *Los Angeles Times* hired a laboratory to test "Alar-free" apples as advertised by five supermarkets in Orange County. In four of the five supermarkets' apples, the survey found Alar.

independently for residues, both the testing equipment and the testing procedures could determine the results. The CDFA state residue testing program, with the particular testing equipment and tests it has used, has found no detectable residues on 80 to 85 percent of conventionally grown food (CDFA Pesticide Residue Annual Report, various years). More costly and time-consuming tests by the U.S. FDA, however, detect residues in about 50 percent of conventionally grown food. Clearly, detecting residues depends on the sophistication of the testing devices (Winter, 1988). Moreover, if the level of residue discovered falls below a certain limit, then no detectable residue is reported.

Certification of farming practices is an alternative type of guarantee that residues are minimized. The CCOF certifies that food with its label is grown in accordance with certain practices. Yet even a CCOF label is no guarantee. Chemical residues can occur in perennial crops treated previously with systemics, from soil saturated during previous years, from irrigation water, or by drift from neighboring fields.

Some consumers may be willing to pay a premium not only for lowered residues but also for a reduction in negative externalities due to adopting low-input agriculture. For example, an apple may be advertised as Alar free or as free of residues from a particular list, but that is not the same as organic agriculture—grown in a manner that avoids contributing to detectable residue on the food, in groundwater runoff, on farm workers, and on wildlife, and to the other negative externalities noted above. Because the term chemical free is not defined legally—as organic is in some states—some consumers may be confusing chemical free with organically grown and paying a premium for the perception that a change in farming practices has occurred.

Among the product characteristics that some consumers value are whether residues can be detected, whether residues exist irrespective of whether they can be detected, and whether externalities occur as a result of the method by which the food was produced. The costs of presenting consumers with this product information through the market could be reduced if legal definitions were used to aid consumers regarding the characteristics of commodities they are purchasing. This is the third prescription. At the federal level, legislation has been proposed—the Farm Conservation and Water Protection Act of 1988—to direct the Secretary of Agriculture to define organic. As noted in section III, California already has defined organic. Additional definitions, such as IPM and chemical free, could be forthcoming under the proposed federal legislation. However, they would require additional legislation in California.

All three proposed policies confine government policy to enhancing information and consumer choice. For each policy proposal, the administrative costs are small, the costs are confined to limited time periods, and neither consumer choice nor producer choice is restricted. These are characteristics of policy changes with favorable probabilities of implementation. They are one-time intervention policies to reduce transition costs in developing a new market for organic food in supermarkets.

### B. *Competition Between Conventional Agriculture and Low-Input Agriculture*

Federal policies (Baker, 1987, 1988, 1989) impose financial penalties on farmers who adopt low-input farming methods. For some price-support policies (Duffy, 1987), the base acreage determines the amount of price support. If those crops are rotated—an important part of sustainable agriculture—then the price support is lost. As another example, the cotton price support is based on yield, so that low-input methods with corresponding lower yield—and lower input costs, but possibly higher profit—result in a smaller price support. The current farm policy debate includes proposals to decouple government payments from production acreage. Decoupling farm income programs from commodities, yields, and acreage has even greater merit. Debating over whether a farm income support policy should exist is beyond the scope of this paper. Rather, the focus here is on the form of any specific program. Alternative farm income support programs, such as income insurance, should be identified and developed in the current debate. As another alternative, income policy could be tied to sustainable management practices. For example, instead of leaving "set-aside" land fallow, the program could encourage planting legumes that fix nitrogen so as to reduce the need for herbicides and nitrogen fertilizer.

Federal and state laws allow cosmetic standards to determine which fresh fruit and vegetables reach the market. Otherwise nutritious and tasty food is culled if it cannot meet standards for appearance. Cosmetic damage sometimes can be reduced by applying pesticides. This results in resurgence and secondary outbreaks requiring additional pesticide applications. Marketing boards are not permitted to price as a monopoly. During seasons of high yield, however, the cosmetic standards are enforced more vigorously (Van den Bosch, 1977). Cosmetic standards could be eliminated. In the context of an IPM program, crops grown without pesticide applications for cosmetic purposes could be marketed with an IPM label. Federal and state laws would have to be changed.

The most important policy change needed is for increasing research and education on sustainable agriculture. Over $1 billion is spent annually on federal and state research and extension on conventional agriculture, compared with about $4 million spent for the LISA. LISA research is likely to ease the transition from conventional systems to sustainable systems and thus reduce input costs, increase yields of non-chemical methods, and improve marketing of organic food. Specific research recommendations follow.

Weed control was the problem cited most frequently in one survey of farmers (Baker and Smith, 1987). Conventional control is primarily by herbicides and then by cultivation. Both methods reduce the natural tendency toward diversity in the ecosystem (Baker, 1988). Yet non-crop species of plants can fix nitrogen, provide beneficial insects, improve water infiltration, increase the porosity of the soil, and increase organic matter. Specific forms of biological control include weed foragers, pathogens, and allelopathy. Irrigation strategies also hold promise.

The central aspect of weed control research must revolve around a systems approach that integrates irrigation strategies and/or biological controls into the crop ecosystem. For example, developing allelopathic crops or incorporating nitrogen-fixing properties into common weeds might be possible, perhaps with genetic engineering. Irrigation strategies might combine deep planting with heavy irrigation so as to encourage root development of the crop and early germination of shallow weeds, followed by water deprivation so as to kill shallow-planted weeds with root systems less developed relative to those of the deep-planted crop. In this manner, through careful timing, monitoring root development of weeds and the crop, and monitoring the soil moisture profile, farmers can kill weeds without killing the crop by depriving weeds of water. Perhaps researchers could develop crop varieties with root characteristics or other moisture-gathering or water retention characteristics for use in a particular irrigation strategy.

Biological insect control is the use of natural predators, parasites, and pathogens to keep the pest populations in check. One strategy that entomologists use is to search for other areas in the world where the pest exists and then focus their search for biological controls at an altitude providing a climate matching that of the crop grown in the United States. Benefit–cost analyses (Norgaard, 1988; Lichtenberg, 1987; Graebner, 1982; Greathead and Waage, 1983) have found uniformly that the benefits of such research far exceed the costs. Once biological controls are established, the marginal cost of beneficial insects is zero; the insects are non-excludable and non-depletable, classic examples of public goods.

Cultural control of insects is the physical modification of the environment so as to disrupt pests and encourage beneficial insects. Research opportunities exist for introducing and maintaining beneficial insects, crop timing, rotations, and multiple cropping systems. Cultural control also is a public good (Lazarus and Dixon, 1984).

Mechanization increases fixed costs while it lowers marginal costs, and this adds to economies of scale. In addition, equipment has become specialized and thus inflexible. Specialization and scale have made most machinery suitable only for a large monoculture typical of conventional agriculture. Research is needed for equipment flexible both in rotations and in multiple-crop fields, rotated polycultures.

### C. *Accounting for Externalities in Policy Design*

The purpose of this paper is not to review all of the state and federal regulatory agencies that implement policies to internalize negative externalities directly from conventional agriculture by the command and control instruments discussed in section II. Nor is its purpose to examine in depth all policies based on economic incentives that internalize negative externalities directly. Only to the extent that economic incentives simultaneously internalize negative externalities directly and reduce negative externalities indirectly does the discussion extend to both types of economic incentives.

The standard list includes five policies reliant on economic incentives: effluent charges, tradable permits, input taxes, subsidies, and torts. The first three economic incentives have two effects: One is direct and the other is indirect. Subsidies have an indirect effect. The first three policies will tend to reduce the amounts of synthetic chemicals used in conventional agricultural and thus internalize negative externalities directly. The indirect effect is that internalizing the negative externalities of conventional agriculture changes the relative profitability away from conventional practices and toward sustainable practices. In this sense, economic incentives that internalize negative externalities directly also provide an incentive for adopting sustainable agricultural techniques and thus reduce negative externalities indirectly.

Section II argued that the failure of command and control policies derives partly from the nonpoint nature of pollution from synthetic chemicals. As Tietenberg (1984) observed, liability law is an insufficient solution due to the burden of proof. This point is underscored by the nonpoint aspect—i.e. proving who is responsible—but also by the scientific uncertainty of the health risks. Tradable permits and emission taxes also are not practical in this situation since the Pareto optimal values vary substantially and unpredictably (Griffin, 1987). This is due to the spatial aspect of nonpoint pollution and to the persistence of many synthetic chemicals and their breakdown products.

The remaining two alternatives are input taxes and subsidies. These two policies are not substitutes, and the Coase Theorem does not apply due to differential monitoring costs. In particular, taxes can be monitored easily relative to subsidies for particular practices. Consider that under the proposed Farm Conservation and Protection Act of 1988, participants must allow representatives of the Secretary of Agriculture to enter the farm to certify compliance with particular agricultural practices so as to qualify for low-interest loans, reduced federal crop insurance premiums, and deficiency payment adjustments.

Subsidies are more likely policy changes than are taxes on chemicals due to two important political considerations: the redistribution of wealth and the international competitiveness of U.S. agriculture. Chemical taxes harm directly both chemical companies and farmers using conventional agricultural practices. Subsidies help farmers and harm chemical companies only indirectly to the extent that low-input agricultural practices reduce purchases of synthetic chemicals. Relative to imported agricultural commodities, subsidies increase U.S. competitiveness while taxes do the reverse. Attesting to the likelihood for subsidies over taxes is the fact that proposed federal legislation includes the former but not the latter.

## VI. CONCLUDING REMARKS

Policy choice relates partly to the importance attached to preserving freedom of choice. Existing regulatory programs rely on command and control regulations that restrict production decisions to internalize the externalities directly. Conversely, three policies proposed in this paper are designed to improve the efficiency of the market for organic food, reduce externalities indirectly, and increase consumer choice through the availability of organic food in supermarkets.

Other significant parts of policy formation are correcting for market failure due to negative externalities and correcting for the inadequate provision of public goods. Information is a public good that is non-rival in consumption and non-exclusive. Government provision of information is applicable at the following levels: consumers, supermarket chains, producers, distributors, and research on sustainable agricultural practices. Information on the profitability of marketing strategies for organic food could persuade supermarket management to advertise so as to attract additional customers with food labelled as organic, CCOF, chemical free, or IPM. During the expanding stages of the market, greater market efficiency could be achieved by providing information on market prices, names of distributors and farmers, volume of sales, and product characteristics to producers, distributors, supermarkets, and consumers. Last, but not least, increased research and education on sustainable agricultural practices are critical.

Policy effectiveness and implementation costs help determine whether the policies' benefits are greater than its costs. Some have criticized command and control policies because of slipping deadlines to review pesticide registration. During congressional reviews, the EPA has argued that it lacks both the time and the resources to meet the deadlines. Indirect methods that internalize externalities and emphasize economic incentives deserve a larger role in the public debate. At a minimum, policies should not favor conventional agriculture over low-input agriculture. At best, policies should provide incentives for farmers to adopt sustainable agricultural practices such that the incentives account for negative externalities resulting from conventional agriculture.

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