Once the emphasis has shifted from the decision between home and commercial production to the market arena as the source of all the available options, the means for household production were gradually lost. This is so for two reasons. As families do progressively less of their food preparation, there is less need for appropriate utensils. More importantly, knowledge about food handling techniques is gradually lost since there is less need and opportunity to pass it along to subsequent generations. An historical review of cookbooks bears this out in that instructions are amazingly elementary and condescending. (5) This loss of technique and experience has the effect of further enhancing prepared foods or mixes in that their end results are standard and predictable even though of a lower quality.

CONCLUSIONS

Dietary habits are complex as are the processes by which they change. By presenting the material in this paper I have not intended to convince readers company advertising and consumer educators have been wholly responsible for the poor quality of contemporary diets. Indeed, U.S. dietary patterns have never been exemplary. Furthermore, I believe that there is some validity to the consumer sovereignty theory. But before consumers could choose, they had to learn that role.

I have argued that a variety of change agents with assorted motivations assisted in the process of "manufacturing" consumers during the late nineteenth and early twentieth centuries. Whether those agents were paid spokesmen for food companies, entrepreneurial experts who tried to make names for themselves, liberals who espoused progress through science, or women who sought higher prestige through professionalism, the results were generally the same. That is, through persuasion and socialization, working class families joined the consumer society. They could enjoy a materially more comfortable life while serving as new consumers--who would eventually be joined by all members of our society -- abdicating their knowledge about and control over the food they ate. The result would lead to even greater dependency on commercial and industrial suppliers of food as well as on expert advisors who teach consumers how to choose wisely.

In recent years there has been considerable interest in the U.S. for fresher ingredients and food products made "from scratch". Although I favor such a movement, I also recognize its limits. Among those who have adopted the values for home made foods, time constraints severely limit the frequency of such production. And, as the movement is associated with gourmet foods, not all classes have been affected. If history teaches us anything, the movement will no doubt spread to more people in a democratic fashion. But all the while, producers and sellers will benefit from the new market opportunities whose outcomes they will carefully channel and control.

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CONSUMERS' STAKE IN FOOD AND AGRICULTURAL POLICIES

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ABSTRACT

Beyond the traditional concerns about an abundant, nutritious, and safe supply of food, consumers are impacted economically by food and agricultural policies. Although the real price of food has fallen, tax costs have risen. How various policies affect food prices and taxes is illustrated; costs of current policies are projected.

INTRODUCTION

The purpose of this paper is to explore the question, "What are consumers' economic interests in food and agricultural policy and how well are they served?" First, various consumer concerns with food and agricultural policies will be outlined. Next the economics of various agricultural subsidy programs will be presented with consumers' benefits and costs identified in each one. The paper will conclude with a brief discussion about the future nature of consumers' concern with the economic outcomes of food and agricultural policy.

CONSUMERS' CONCERNS WITH FOOD AND AGRICULTURAL POLICY

Food Price and Supply

The overall purpose of food and agricultural policies is to assure an adequate, safe supply of food for all consumers at a reasonable price, as long as that price allows a fair return to productive resources, mainly to farmers. This charge, to simultaneously serve the interests of consumers, protect the welfare of producers, and ensure an adequate food supply, has led to a hodge-podge of policies. As a group, they have sent mixed signals to producers, raised some food prices, and lowered others. A delicately balanced political coalition perpetuates a "jerry-built" package of policies that, ostensibly, can serve two masters.

Scholars of agricultural policy -- specifically farm policy -- have been exuding admonitions over the last few years about the need for fundamental changes. In spite of a plethora of research and rhetoric to the contrary, the 1985 Food Security Act made few changes in traditional agricultural programs. Consequently, the tax costs of farm programs will continue to be high. Excess supplies of basic commodities will continue. And, commodity trade groups will increase efforts to increase consumer demand for their particular type of food. Herein lies one of the basic dilemmas in food and agricultural policy. Incentives to increase production and efforts to sell more food domestically continue among a population whose largest dietary problem is obesity and where per capita food consumption is unlikely to increase.

Why do we, as a society, encourage and approve of agricultural policies that foster long-run excess supplies? Five reasons come to mind: (1) Excess supplies put downward pressure on food prices. Except during the 1940s and again in the 1970s, real food prices fell throughout this century. Over that time period, the cost of food relative to the purchasing power of an hour's work fell at an average rate of 1.5 percent per year [2, p. 12]. (2) Maintaining farm prices above the market equilibrium kept farm incomes relatively high and helped preserve a rural-farm lifestyle. (3) Excess supplies of basic food commodities (especially grains) are desirable as a tool of foreign relations. We use food to reward our friends, ensure our allies, or to punish our enemies. (4) The Malthusian hypothesis leads the United States to view itself as the bread basket of the world. Maintaining productive capacity and inventories of food that could be used to forestall an occasional famine somewhere in the world was (and is) considered a decent, humanitarian thing to do. (5) Supplies in excess of domestic demand were believed to be saleable on the export market. Indeed, agricultural commodities comprise about 19 percent of all U.S. exports. There has been a positive trade balance in agricultural products since 1960 and they have helped the United States to have a more favorable balance of payments than would otherwise be the case.

While many government farm programs have encouraged excess supplies of basic commodities (mainly food and feed grains, cotton, sugar, and milk), various other programs limit the quantity of specific foods that can be sold on the market. These policies tend to raise both farm and retail food prices. Restricting supply for the purpose of raising prices is clearly not in consumers' interest.

Tax Costs

Beyond the concern for low retail food prices consumers' have a stake in the tax costs of farm subsidies. Between 1981 and 1983 these costs quadrupled from \$5.6 billion to \$22.9 billion. They comprised about 2 percent of total federal expenditures, costing U.S. households an average of \$178 each in 1982. They are estimated to average about \$20 billion per year through 1989 and will comprise over 60 percent of net farm income by 1988 [16, pp. 23 and 30]. Not surprisingly, public concern about these costs is rising. Further questions are raised about the income distribution effects of farm subsidy payments since they are transferred from largely middle income house-

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holds to upper income farmers. In 1985, 57 percent of the farm subsidies were distributed to the 17 percent of the farmers who had annual gross sales of over $100,000 and who earned 85 percent of all farm income [1].

Other Food Policy Concerns

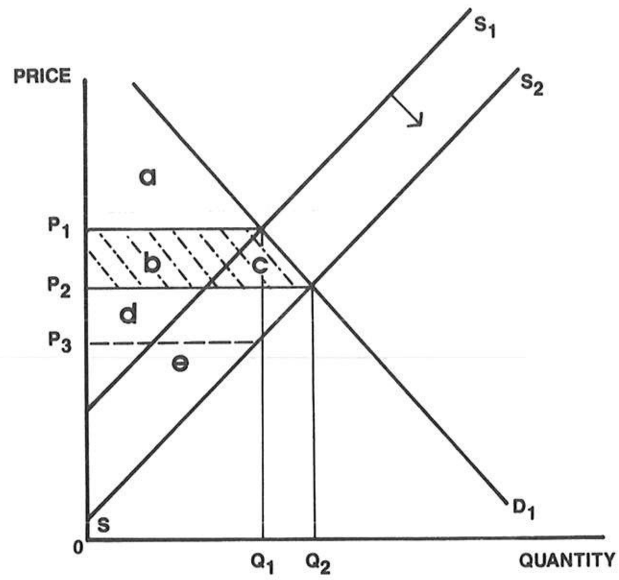
Consumers' concerns with food and agricultural policies that are largely independent of farm programs include quality, safety, variety, convenience, and information. Part of food quality and safety characteristics are nutritional and health standards which continue to change as new information becomes available. "Food policy," as it is known in this country, has focused primarily on ensuring a safe and nutritious food supply and on ensuring adequate nutrition to the poor. The latter emphasis may be more accurately identified as a "poverty policy" even though it was initiated and is administered by the U.S. Department of Agriculture. The tax cost of these programs ($18.1 billion in 1983 and 1984) is roughly equal to the costs of subsidizing farm production ($18.2 billion averaged over 1983 and 1984). They can be justified (or not) on the same basis as other poverty programs but they should not be construed as food policies that impact heavily on the well-being of the majority of consumers. Consumers, as consumers, are concerned with a steady supply of high quality, safe food at the lowest possible cost.

ECONOMIC OUTCOMES OF AGRICULTURAL POLICIES

In order to trace the predicted changes in consumers' welfare that emanate from government policies to support agricultural production and provide income security to farmers, one needs to begin with the Hatch Act of 1887 that set up a series of federally funded, agricultural experiment stations to conduct agricultural research in Land Grant Colleges and Universities across the country. Extension programs were added by the Smith-Lever Act of 1914. Publicly funded agricultural research and extension resulted in technological innovations and management skills that lowered the production costs and improved the efficiency of agriculture. In addition to a more abundant food supply at lower real costs to consumers, these productivity gains released resources from agriculture so they could be used to produce other consumer goods and services. The return on public dollars invested in agricultural research in the United States is estimated to be between 36 and 42 percent or about three times the before tax rate of return obtained from investments in manufacturing [11].

Assuming a fully informed, competitive market, the economic impact of improved technology can be illustrated most simply by an outward shift of the supply curve. In Figure 1, the supply curve S_1 shifts to S_2 when the costs (P_1) of producing the original quantity, (Q_1), are lowered to (P_3). The equilibrium (or market clearing) price falls to P_2 and the quantity bought and sold increases to Q_2. Consumers gain by being able to buy more food at a lower price. Consumer welfare (as measured

FIGURE 1. Technology Increased Supply



by changes in consumer surplus)[2] increases by the crosshatched areas b + c. Area b is transferred from producers to consumers but producers enjoy a net gain in producer surplus equivalent to area e - b. The net gain to society from lower prices induced by higher productivity is equivalent to area c + e where c goes to consumers and e to producers. Improved technology in the form of hybrid seeds, pesticides, feed supplements, and new genetic discoveries yet to come, continue to put this type of downward pressure on the market clearing price of food. The best evidence of this phenomenon in the United States is the declining average portion of income necessary to purchase food -- from about 35 percent in 1940 to 14.5 percent in 1985. This is even more impressive if one realizes that over that time the portion of food expenditures going for marketing and convenient services rose from 50 percent to 73 percent.

In the case of some food commodities, Figure 1 would be more realistically illustrated by Figure 2 where demand is not very price elastic (about .32) and short-run supply is perfectly inelastic. As S_1 goes to S_2, the price drops rapidly. If S_2 were to move out to S_3, supply would move beyond demand at any reasonable price. This extreme case is a conceivable scenario if consumers' demand for some foods becomes satiated and productivity increases continue.

The next step in agricultural policy came when the depressed market price (P_2 in Figure 1 and 2) was found to be inadequate to cover production and marketing costs. One of the government programs designed to raise the price received by farmers

[2] Consumer surplus is the area above the price and below the demand curve. It represents the monetary value of utility received above that which is paid for in the marketplace.

FIGURE 2. Short-Run Supply and Demand For Agricultural Commodities

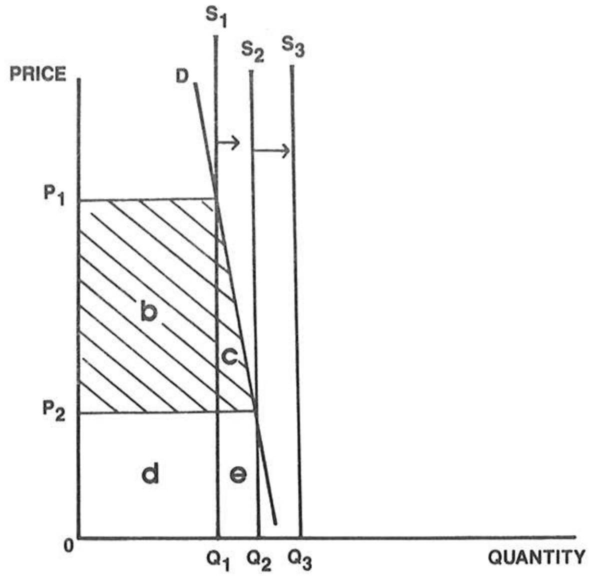
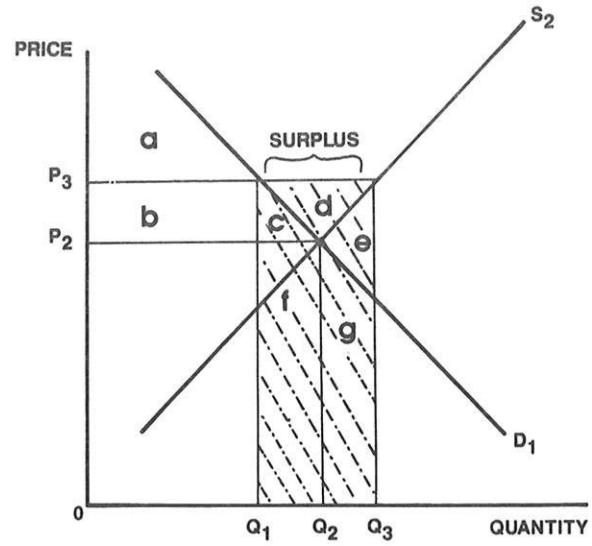


FIGURE 3. Commodity Price Supports



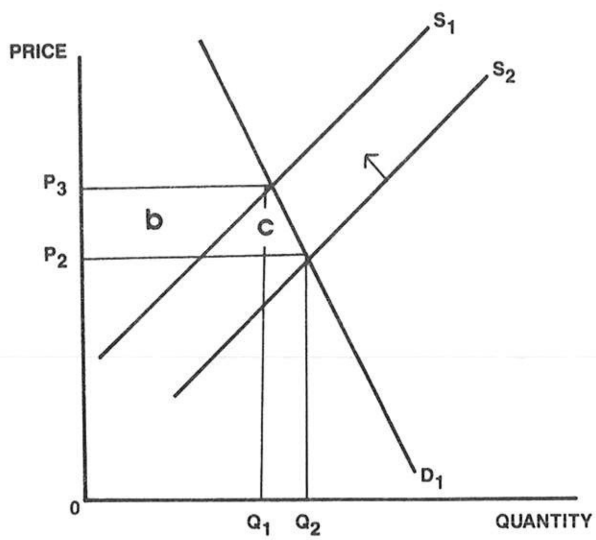
was support prices, illustrated by Figure 3. Assume price P_2 is unacceptably low for farmers. The government raises the market price to P_3. Farmers respond by producing more (Q_3) and consumers respond by buying less (Q_1). A surplus equal to Q_3-Q_1 now exists and the government must decide what to do with it. Typically, the government purchases the excess, stores it, and eventually distributes it through nonmarket channels. Domestically, it could be distributed through commodity distribution or school lunch programs. Internationally, it could be donated to hungry people in developing nations principally through PL480 programs.[3] The commodity support price, (P_3), reduces consumers' well-being by decreasing consumer surplus equal to areas (b+c). Producers' surplus increases by areas (b+c+d); there is a net gain to producers equal to area d. The tax costs of this type of price support equals areas (c+d+e+f+g). Subtracting out area d (the net gain to producers) leaves area (c+e+f+g) as a net tax cost (welfare loss) not counting the costs of storage, handling, and distribution. If the government could sell the surplus commodities it had purchased at, for example price P_2, it could recapture areas (f+g+1/2e) and the net welfare loss would be areas (c+1/2e). Occasionally, government sales of surplus food are a self-defeating activity. If the buyers of government surplus commodities are reflected in the original demand curve (D_1) government sales compete with the private suppliers and the market price falls back towards P_2. Therefore, the government must seek "new markets" in which to sell surplus foods. Foreign countries with unexpected, but temporary, food shortages provide an opportunity for selling the excess supply from time to time. One such opportunity was largely responsible for this price policy falling into political disfavor, namely the 1972 Russian grain deal. Russia unexpectedly purchased 400 million bushels of wheat. In Figure 3, assume the sale of that wheat equaled Q_3-Q_1 and that the world price equaled P_2. The U.S. government ended up subsidizing the sale of that wheat by the equivalent of areas (c+d+1/2e), which equaled about \$150 million. This means that U.S. taxpayers/consumers subsidized the Russian consumers by \$150 million through the sale of grain at a price below the domestic price (P_3) [8, p. 221].

Although support price mechanisms like this have been largely replaced by other pricing schemes, current political pressures to institute export subsidies would have a similar effect. Other countries would purchase our food at world prices which are below our domestic prices and the government would pay the difference to the producer. Local consumers would transfer income to farmers and subsidize foreign consumers through lower priced food in foreign countries.

Government policies that hold farm prices above a market clearing price tend to increase supplies, reduce consumers' welfare, and increase government costs. Counter measures have been instituted to control the quantities of food produced or marketed. The economics of these measures are simple; the implementation has proven inordinately compli-

[3] PL480 refers to a U.S. subsidized sale of food to a developing country under one of three titles of the Agricultural Trade, Development, and Assistance Act of 1954. It is sometimes referred to as the "Food for Peace Program." (i) These sales extend long-term, low interest credit to the buying nation to be used to buy food from private U.S. suppliers and resell it to their consumers. (ii) The United States donates food for emergency needs and specific nutritional problems. (iii) Food is donated over several years to very poor countries who are undertaking specified development projects.

FIGURE 4. Production or Marketing Controls



cated and costly. The economics is illustrated in Figure 4. The idea is to shift the supply curve back to S_1 so that the market clearing price will rise to P_3 -- a price that would provide a fair return to farmers. The loss of consumer surplus under this scheme is the same as in Figure 3 (area b+c) but the gain in producer surplus is limited to area b. Area c represents the net welfare loss to society. If S_1 could be insured by fiat or by voluntary action there would be no tax costs. Schemes to move S_2 back towards S_1 have, in fact, cost billions of public tax dollars and billions more in private assessments that producers impose on themselves.

The major schemes to reduce the excess supply of agricultural products have been acreage controls and marketing orders or agreements. Acreage controls involve direct payments to farmers for not planting crops on part of their land, such as the soil bank program of the 1950s and 1960s. In 1986 similar programs are called acreage reduction and conservation acreage reserve. Acreage reduction schemes have been largely unsuccessful for decreasing supply. Typically the least productive land is idled and farmers increase the yields on their remaining land through a greater use of fertilizer, water, and other technology. To the extent that acreage controls are successful they reduce consumers' welfare, lead to decreased agricultural wages, labor supply, and output but increase returns on land in both the agricultural and manufacturing sectors [12].

Marketing orders or agreements are individually designed for specific food commodities and usually restrict the quantity of that food that can be sold in the market. The costs of enforcing marketing orders are borne largely by the producers but their self-imposed taxes, quotas, and standards receive the force of law. It amounts to a government sanctioned and enforced cartel of producers of specific agricultural commodities. Marketing orders have been a relatively effective tool for increasing prices and for controlling supply -- an explicit feature of about one-fifth of the federally operated marketing orders.[4] Consumers benefit from marketing orders, it is argued, because they enforce consistently high quality standards on the products sold. In some cases they help to ensure a year-round supply of otherwise seasonal foods. In an affluent society consumers may be willing to pay more for higher quality food but it does not negate the fact that, in most cases, more of these foods could be marketed at lower prices.

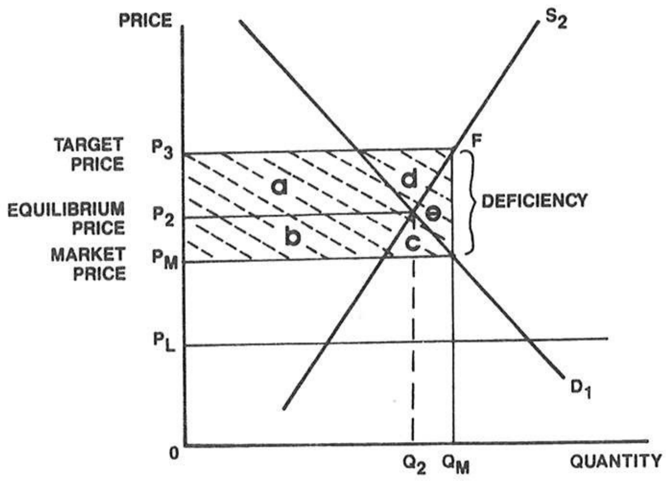
A more "market-oriented" agricultural policy was called for in the 1973 Agricultural and Consumer Protection Act. It is still the buzz word for policy reform. The pricing scheme to come out of the 1973 Act allowed lower market prices for consumers while guaranteeing a higher (fair) price to farmers. In Figure 5, P_3 (the old support price) is now called a target price. It is the price farmers will receive for their products as long as they sign up for the program.[5] This scheme as adopted for food and feed grains, cotton, and wool covered about 36 percent of the total value of all domestic agricultural production in 1983. If the market price rose above the target price, then the target price would become irrelevant. The market price is usually determined as the price consumers are willing to pay for the quantity supplied (Q_M in Figure 5). The difference between what consumers pay (P_M) and the price participating farmers were guaranteed (P_3) is made up by the government through a "deficiency payment" equal to the crosshatched area of Figure 5. Under this program, consumers' welfare is increased in the marketplace by areas (b+c) and producers' welfare is increased by areas (a+d). The tax costs equal the areas (a+b+c+d+e) with area e representing the net social cost of this scheme.

Direct cash payments to farms, most of which were for deficiency payments, amounted to $9.3 billion and $8.4 billion in 1983 and 1984, respectively. In those years, deficiency payments comprised 62 and 24 percent of all net farm income, respectively. It is politically very difficult to lower target prices. The 1985 Food Security Act froze them at their 1985 levels for two years. Direct farm payments for crops are therefore projected to be $10.7, $14.2, and $15 billion in 1986, 1987, and 1988, respectively [16, p. 21]. As long as the target price is above the equilibrium price (P_2) it encourages excess production which pushes

[4] In 1981 there were 47 federal marketing orders for fruits, vegetables, and specialty crops. These accounted for about 8 percent of total farm receipts for crops. In addition, there are marketing agreements for peanuts, both federal and state milk marketing orders, and miscellaneous other state operated marketing orders [14].

[5] Signing up for the program entails a promise to idle a specified portion of land. Participants become eligible for government production loans but are not obligated to take them.

FIGURE 5. Target Price/Deficiency Payments



down the market price and increases deficiency payments. The major difference between this target price program and the support price program in Figure 3 is that, with target prices, the market price can fall encouraging consumers (both foreign and domestic) to buy up the excess supply rather than the government having to purchase it. Consumers' market price of food is lower than with support prices, but the tax costs can be very high. Other consequences of the target price/deficiency payment program include a tendency for wages and the labor supply to be relatively high in agriculture compared to other sectors and for the returns to agricultural land to increase. The results increase agricultural production at the expense of other consumer goods and services [12].

There is a limit to how far the market price can fall in the target price/deficiency payment scheme. The floor on the price is known as the "loan rate" (P_L in Figure 5). The loan rate is the amount of money per unit of production that a participating farmer can borrow to cover annual production costs using future crops as collateral for the loan. If the market price of the crops falls below P_L, the farmer turns the crops over to the government and does not have to repay the loan. The farmer also receives a deficiency payment of $(P_3-P_L)Q_M$ for the quantity of crops turned over to the government. In this case consumers loose all the consumer surplus because nothing is purchased in the market and the tax costs would equal the rectangle (OP_3fQ_M) in Figure 5. In reality P_M rarely falls below P_L, but the closer together they are, the higher are the deficiency payments and, therefore, the tax costs. Recently the price of at least two major crops covered by this type program, corn and wheat, are riding on the loan rate.

As illustrated above, consumers' benefits and costs of government schemes to juggle prices and quantities of agricultural supplies are mixed. Different foods are subject to different programs and quantities supplied and market prices vary from year to year. It has been estimated that consumers pay about $9 billion per year more for food in the market place due to various government programs that restrict supply and/or raise the market price [4]. This is a number subject to much variation over time and over estimating techniques and model assumptions. The bulk of the tax costs go for deficiency payments to farmers of grains (corn, sorghum, barley, wheat, and rice), cotton, and wool. In 1985, $8 billion was spent for these payments. Without target prices and deficiency payments, the supply of these products would eventually fall and the market clearing price should be restored at P_2 in Figure 5. Estimates show that if this were to happen, the prices of basic agricultural commodities would fall 15 to 20 percent while consumers' price of meats (beef, pork, and poultry) would decrease only slightly, about 3 percent [7, pp. 54-55]. Estimates of future retail prices of meat under different policy scenarios show that for beef and pork there is little difference between the current program with target prices and a more "market oriented" option without target prices but retaining loan rates and acreage controls that would set a price floor.

Under the 1985 law, retail beef prices are projected to rise about 8 percent in 1987 and fall back 8 percent in 1988. Chicken and pork prices are projected to fall about 18 percent by 1988 [16, p. 16]. Similar estimates are not currently available for other types of food but meat comprises about 19 percent of expenditures for food eaten at home. In 1985, United States consumers spent an average of $326 per capita for meat and poultry. An 18 percent decrease in chicken and pork prices would lead to a per capita expenditure of $302 by 1988. However, if consumption patterns continue to shift away from beef and towards chicken and pork, the total per capita expenditure on meats are estimated to increase by about 1.5 percent to $331 in 1988 [16, p. 16]. Declining prices of grains tend to hold down consumers' food costs even though their tax costs may remain high.

POLITICS OF FOOD AND AGRICULTURAL POLICY

Producers of individual commodities such as milk, grain, or beef have been able to organize and to effectively use political pressure to ensure government support for the price of their products. Consequently, farm prices have been supported at levels that yield a fair return on investment for the efficient farmer. As long as supporting farm prices and incomes did not result in excessive government costs or objectionably high food prices, consumers were not politically concerned with these programs. However, in 1972 when meat prices rose 25 percent in one year, consumers began to pay more attention to farm policies and their expected effects on food prices.

The direct (tax) costs are likely to dominate the political rhetoric and may well turn out to be both the larger of the costs and the greater of concerns to consumers. The current financial crisis in much of the agricultural sector will hasten the trend towards fewer and larger farms. Continuing to transfer income from middle-income consumers to relatively wealthy farmers will not make political or economic sense in the long run. Whereas, changes in the price of farm commodities impacts on less than 5 percent of the average consumer's expenditures in the market, higher food prices leads to higher tax payments.[6] As food costs rise, the tax costs of all poverty and welfare programs rise because the definition of poverty and, therefore, the eligibility for most transfer payments is based on the cost of USDA's "low cost diet". As food prices rise the cost of this diet rises, and the tax cost of poverty programs goes up.

Economists have long been writing about and analyzing the impacts of agricultural policies on consumer food prices and consumer welfare. A mere sampling of these studies are included in the reference list [3,4,5,6,9,10,15]. Consumer activists, on the other hand, have only recently become interested. The need for specific calculations of consumers' economic costs and benefits to food and agricultural policies is growing.

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[6] On average, consumers spend 15 percent of income on food but only 27 percent of that pays for the farm commodity (food) portion of the product purchased (15 x .27 = 4.05).

FOOD SAFETY POLICY ANALYSIS: ANALYTICAL METHODS

Carol S. Kramer, Cornell University[1]

ABSTRACT

Four methodologies for evaluating consumer protection food safety regulation are explored: benefit cost, risk assessment, cost effectiveness and program impact analysis. Strengths and limitations including utility for decision makers are discussed. Challenged to integrate data on risks, efficacy, economic costs and benefits to promote acceptable safety, decision makers require appropriate analytical work.

Product safety is an important goal for the food system. Consumer and producer information problems and many externality/public goods qualities of food safety result in public sector efforts to regulate or actually produce acceptable levels of safety.

Legislative, administrative and judicial branches of government formulate, implement, modify, and review food safety policy over time. Two agencies, the Food and Drug Administration and the U.S. Department of Agriculture exercise principle administrative and regulatory responsibility for food safety policy in accordance with established legislation. (The EPA also has a role in regulating pesticide residues.) These agencies use a variety of policy tools. For the sake of simplicity, administrative policy tools can be summarized (8):

1) establishing and enforcing product performance standards (actions may range from a product ban if standards cannot be met to enforcing chemical residue tolerance levels)

2) establishing and enforcing process standards (e.g. current good manufacturing practices, or requirements of best available technology)

3) requiring, supporting or providing information (research, education, public interest announcements, warnings, labels)

In the early 1980s, industry expressed widespread and vocal dissatisfaction with a broad spectrum of protective regulations designed to promote health, safety and environmental quality in the U.S. Dissatisfaction was initially exacerbated by general inflation and recession, now by deficits. Attention focused on the economic and the psychic costs of regulation, to industry and it was claimed, ultimately, to consumers.

A nearly simultaneous development in the last few years has been the rapid advance in toxicological and analytical capacities to detect chemical contaminants and other sources of risk at near zero levels in the food system (1). In many cases scientific and economic incentives appear opposed, particularly as they affect regulators.

The upshot of these developments for regulators has been increasing pressure, if not budgetary support, to rationalize or justify proposed agency "protective" actions on the basis of systematic, economic analysis.

With this assessment in mind, the first section of this paper outlines some of the major analytical tools available for food safety policy analysis. They vary in terms of analytical benefits, costs and risks. The second section discusses factors which constrain the usefulness of analytical techniques for policy makers.

ANALYTICAL METHODS FOR ASSESSING IMPACTS OF SAFETY REGULATION

Literature regarding safety assessment in general, and food safety regulation, in particular has proliferated in recent years (2,3,4,18). Work of the Food Safety Council is noteworthy. Other recent works outline a variety of frameworks for evaluating social policy of the type designated protective regulation (10,18). This paper discusses four general frameworks.

Benefit-Cost Analysis

Application of economic theory to public program analysis over the years has resulted in formal techniques of benefit-cost analysis. Ideally, economists evaluate the benefits of a public program through assessment of what consumers are willing to pay for the program. Costs of the program represent all resources devoted to the program evaluated at their opportunity costs.

In the words of a standard text, economic benefit-cost analysis is a technique for estimating the "total return or productivity or profitability to the whole society or economy of all the resources committed to the project regardless of who in the society contributes them and regardless of who in the society receives the benefits" (6).

Haveman and Wiesbrod (7) note that benefits can only be identified and evaluated with reference to an objective function; the goals of a program serve as the necessary starting point for conceptualization of benefits. Project goals generally fall within two broad categories: improvement of allocative efficiency (seeking an increase in the net value of output through a redistribution of resources); and improvement of equity (redistributing existing resources in order to increase the welfare of particular groups). Schmid (15) cautions that while social benefit-cost analysis

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attempts to draw this key distinction, care should be exercised to reveal the normative nature of both objectives. Analysis of most public programs reveals program objectives and weights that vary among decision-makers. Analysts should consequently specify critical objectives, participant interests and performance impacts in order to assess program performance.

Classical and neoclassical utility theory from Marshall, Hicks and others furnishes the conceptual basis for measuring an individual consumer's demand for a product. The theory develops concepts of consumer's surplus (and the approximate parallel, producer's surplus) as the difference between a prevailing uniform market price for a good or service and the price a consumer would be willing to pay to purchase consecutive units of the good in the absence of a uniform price.

If the analysis of utility and demand remains confined to the individual, under ceteris paribus conditions, and particularly if the good or service in question is free of characteristics associated with public goods, the concept of surplus is relatively straightforward. Net benefits of a project which either alters an existing product's price or provides a new product can be defined in terms of the net change in the area beneath a demand curve and above the market price line. Samuelson states, "At the level of the individual consumer, cost-benefit welfare analysis can be performed rigorously and unapologetically by means of consumer's surplus" (14).

The entire business of welfare analysis suffers a quantum leap in complexity--not to mention controversy--when policy analysis aggregates individuals into a society. One wishes to do this in order to say something systematic about the net economic impacts of public projects. Particularly intractable is the conceptualization and empirical estimation of demand at both individual and aggregate levels for a broad class of "goods" such as food safety not effectively supplied in a market. These goods possess one of a variety of "public goods characteristics." In addition, uncertainty associated with food safety poses problems for consumers, producers, and policy makers. The upshot of all this for food safety policy analysis is that the composite theory of aggregate demand for public goods becomes a very tentatively balanced high rise house of cards.

The theoretical and empirical problems tied up in benefit-cost methodology (as well as the underlying theory of social welfare) imply that while elements of the theory of demand for "goods" such as food safety provide constructs of heuristic value, their applied value in attempting to estimate benefits of public food safety programs falls far short of theoretical promise.

Information problems--inherent uncertainty and high information costs--seriously limit the utility of standard willingness-to-pay conceptual measures of consumer surplus and therefore benefits from food safety programs or projects. Information problems are summarized for the individual consumer in a couple of questions: What is the personal risk now and later of consuming a contaminant? What should be paid to reduce this risk?

Consumer willingness-to-pay for a given reduction in risk depends upon individual patterns of risk-aversity, the price of risk reduction, and the complement of alternative utility-producing goods and services. Included are alternative measures to reduce risk (or increase health).

If one has market data indicative of aggregate demand for "food safety" and, if one can identify effects of a public policy upon the price or availability of the good "food safety," then welfare analysis seeks to evaluate changes in consumer and provider surplus.

Empirical problems in obtaining estimates of willingness-to-pay are summarized by Freeman (5) and Schmid (15), along with possible uses of market data. One approach, based on the assumption of weak complementarity between an environmental good Q and a private good X_i in the consumer's underlying utility function, may offer the possibility of attributing changes in demand for X_i--when at least two distinct levels of Q have been available--to varying levels of Q. A critical requirement here, however, is consumer consciousness of the potential effects of varying levels of the environmental quality variable, a requirement not met in many food safety cases.

Recently, attempts have been made to link willingness-to-pay and human capital approaches in estimation of risk reduction benefits (9). Economists estimate that an individual consumer's willingness-to-pay to avoid expected death-related economic losses constitutes a lower bound for valuing risk to life. Some of these models specify a normative model based upon what a rational individual should be willing-to-pay to avoid financial losses associated with risks to life, assuming the individual is at least as risk-averse with respect to loss of life as to loss of financial assets.

While such normative models show promise within the limits of their assumptions (particularly regarding risk preferences) for expanding the use of benefit assessments for risk reducing food safety regulations, they still rely for validity on the availability of toxicological and other specific data.

Alternative Approaches to Conceptualization of Food Safety Benefits

While conventional economic theory bases demand conceptualization upon individual consumer preferences revealed by willingness-to-pay for a good or service, in practice consumer demand for food safety/public health services frequently cannot be determined in part due to uncertainty, high consumer information costs and other public goods characteristics of food safety.

A variety of attempts to circumvent these difficulties and enable the analyst to say something about the benefits of a public health program has entered the literature. The attempts employ two basic propositions: first, an ability-to-pay or human capital criterion is often substituted for willingness-to-pay; second, the notion of direct cost-savings or averted public health expenditures is counted as an additional measure of public health program benefits. Regarding the former, analysts frequently substitute calculations of changes in streams of income earnings attributable to a program for measures of consumer surplus. In such human capital approaches, positive changes in income streams are netted against program costs to yield a measure of the net benefits of a program.

This technique represents the use of an "ability-to-pay" criterion. As Freeman indicates, measures of willingness and ability to pay are not equivalent conceptually or empirically. Reliance upon income savings carries with it the problematic implicit value judgement that an individual's worth to society is equivalent to his income stream over time. Generally, reliance on income savings in public health program analysis as a measure of program benefits risks biasing results toward those programs which save the lives or reduce the diseases of those earning higher incomes in the marketplace. Hence, such a measure favors selection of a public health program aimed at protecting the affluent rather than the poor or those who do not produce for the marketplace. (Accordingly, the "congressional diseases," cancer and heart disease, would be favored over tuberculosis control, or programs to benefit unwed minority mothers (7)). Since the distribution of dangers from chemical contaminants in food is frequently unrelated to income distribution, this potential bias is probably negligible in many cases.

Ability to pay criteria make assumptions regarding consumer spending preferences which may be unwarranted. Schmid notes that the difference between willingness and ability to pay hinges substantially on the impact of uncertainty and information costs. When consumers are unaware of relative or absolute risks correspondent with various diseases, they make decisions which differ from those rational under more perfect information. They may be unwilling to pay for risk reduction in cases of uncertainty despite ability. Additional considerations involve individual differences in risk aversion. The ability to pay for a program does not reveal willingness. Willingness might not exist under various conditions of information and risk preferences (15).

Cost or Resource Savings

Another category of benefits consists of medical costs formerly expended but averted because of a public health program. Reparative expenditures for disease treatment are included here.

The accuracy of both cost savings and ability to pay calculations depends upon a knowledge of the dose-response curve operative in the population. This information is frequently lacking in food safety cases. Another difficulty with cost savings application to food safety regulations involves the extremely long latency period for some adverse effects, including most cancers.

Surveys and Non-market Alternatives to Willingness-to-pay

In the absence of market data, non-market methods of estimating willingness to pay are attempted. Many of these alternatives have their own limitations. Surveys and voting schemes contain problems relating to possible strategic behavior on the part of resondents, biases, and the lack of incentives to accurately answer survey questions. Despite the limitations, surveys sometimes provide some of the only information available. Advances have been made in survey methodology and analysis.

For the policy maker, effective use of such methods is sometimes difficult. In addition to the lack of adequate toxicological information, resources and approval for collecting survey data are frequently limited.

Economic Costs in Benefit Cost Analysis

The preceding sections discussed the theory of demand and benefit determination along with the potential for application to public food safety programs. Benefits were found to be of two major conceptual types: 1) an increase in public health, ideally (but often not practically) evaluated according to consumer willingness to pay; 2) a resource savings stemming from averted costs of morbidity or mortality (conceptually problematic but more manageable empirically.)

On the flip side of the ledger, economic costs associated with a public health or food safety regulatory program are categorized in terms of those resources invested in the program valued at their opportunity costs.

Dividing the world simply into consumers and producers, then each group can experience benefits and costs from a project. Benefits and costs to consumers are evaluated in benefit-cost analysis according to changes in consumer surplus. Benefits or costs to producers (an increase or decline in factor prices or opportunities) are measured by alterations in economic rent. Mishan notes that, in practice, an asymmetrical treatment of impacts is involved in the usual practice of accepting factor prices as given. He states:

This asymmetrical treatment is not wholly unwarranted in an economy where factor groupings are few, but where product groupings are many. A project that increases the output of a product or service may result in large changes in its price without appreciable effects on the relevant factor prices (12).

When assumptions of unchanged factor prices are unwarranted, techniques of shadow pricing to approximate true factor opportunity costs can be used.[2]

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[2]In calculating net benefits, any difference between the real social cost of resources used and their market cost may be added to project benefits or subtracted from project costs.

In a formal benefit-cost analysis, opportunity costs of the project enter the economic accounting format through the discount rate. Choice of the relevant discount rate, particularly over a period of decades is problematic and frequently crucial to the magnitude of the measure attained. Haveman and Weisbrod state:

Note that in a fully employed economy, the primary benefits also are achieved at the cost of displacing some other project and its benefits. Such 'opportunity costs' must indeed be considered by the cost-benefit analyst. They enter in through the inclusion of an interest rate (cost of capital) and through the estimated cost of purchasing the resources required for the project--resources that must be bid away from competing uses . . . If all other things are held constant, a project which employs idle resources will yield greater net benefits than one which requires that resources be directed from some alternative activity (7).

Currently, there is little agreement about how to treat the asymmetry in timing between project costs (important in the near term) and benefits that tend to be long term.

Risk Assessment

Risk assessment, or risk-risk analysis or benefit-risk analysis are variants or first cousins of benefit-cost analysis.[3] However, these techniques stop short of assigning economic values to various measures of risk or risk avoidance. Rather, analysis results in a schedule that couples: dose with response; health risk from exposure to a substance with health risk from nonexposure (e.g. nitrites); or say, monetary benefits from use of a substance in production and a measure of human disease incidence or avoidance.

Both demand and supply of risk assessment techniques (and analysts) have escalated in recent years, presumably reflecting heightened recognition of the necessity of accepting some risk in return for a variety of economic benefits and a reluctance to place explicit monetary values on human life and well-being.

In a widely read summary of important elements of risk analysis, Lowrance defines a set of terms: efficacy, risk, benefits, costs and safety (11). The first two, efficacy and risk, are physically measurable or probabilistically inferrable quantities. The efficacy of a product or process refers to technical efficiency in terms of input-output relationships. Risk pertains to the probability of certain causal relationships occurring between exposure to a source of hazard and potentially adverse effects of that exposure.[4] In both regards our techniques of measuring efficacy and risk are notably imperfect; however, they can be expressed as physical relationships in probabilistic terms preferably denoting range rather than point estimates of risk.

With benefits or costs, however, one enters the realm of economics by attempting to impute economic values to various levels of efficacy or risk. The previous section reviews economic conceptions of benefits and costs in some detail. One important distinction between risk and benefits and costs is that between positive and normative measures.[5]

Beyond the "scientific" determination of product efficacy or risk and the "economic" estimation of associated benefits and costs, one enters the realm of social judgement regarding safety. "Safety" can be defined as socially acceptable levels of risk. Determination of safety involves implicit or explicit balancing of many factors, some physical, some economic and others associated with societal values as to levels and types of risk that are reasonable.

Criteria of "reasonableness" emerge over time and relate intimately to social definitions of fairness. Dimensions of reasonableness of risk include: whether risk is assumed voluntarily (and with accurate knowledge of effects) or borne involuntarily; whether effects are serious or slight; borne by many or few; appear immediately or are delayed far into the future; whether exposure is essential or a luxury; whether alternatives to the exposure are available or not (11).

To summarize: risk analysis provides a valuable tool for identification of some of the foundation stones upon which economic and societal evaluations or trade-offs between product risk and efficacy must necessarily be made.[6] It should be understood, though, that risk analysis is usually highly uncertain and, resource requirements for conducting the necessary physical experiments are substantial.

Cost-Effectiveness Analysis

Cost-effectiveness analysis begins with a policy prescription and attempts to identify the least-cost means of achieving the prescribed end. For

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[3]I'm distinguishing here between "risk analysis" used generally and techniques of "quantitative risk assessment" particularly aimed at extrapolating high-dose/small sample animal tests to low-dose human results.

[4]Four categories of essential questions contribute to assessment of risk: 1) define the conditions of exposure (who is exposed?, to what levels?); 2) identify adverse effects; 3) relate the exposure to effects; 4) estimate overall risk.

[5]All measures are normative fundamentally. Input-output formulations depend upon normative definition of "product" and "waste"; risk measures similarly depend upon estimations of "undesirable" hazard.

[6]For an informative discussion of information requirements for an ideal risk-benefit analysis, see van Ravenswaay and Hull (17).

example, one might establish the goal of eliminating sulfa residues in swine and then evaluate alternative methods of achieving the reduction.

Cost-effectiveness analysis, in effect, ignores the question of benefits, either absolute or relative. Again using the sulfa example, cost-effectiveness analysis does not attempt to estimate the value of achieving reduction of sulfa residues in terms of public health or the relative contribution to public health of a sulfa program vis-a-vis tuberculosis or alcoholism programs of equivalent cost.

Benefit-cost analysis, then, is preferred for informing broad choices between alternative policy programs. It is more complex to conduct than cost-effectiveness analysis, however, requiring information regarding benefits. In the measurement of public health impacts from food safety regulatory programs, many gaps exist in our understanding of the risk associated with exposure to chemical residues in foods, across the population and over time.

Impact Analysis

Impact analysis approaches the task of public program analysis from a slightly different, more objective perspective and employs a different framework than the methods outlined above.

Rather than attempting to net social costs or risks against benefits to determine changes in social welfare, impact analysis establishes causal links between a program's use of inputs, performance of activities, production of outputs, and ultimately, measurable effects.

Definition of program goals and objectives is critical in subsequent design of the program information structure. Objectives may be broadly or narrowly conceived. Emphasis is generally placed less upon the identification of program impacts upon global measures of welfare than on program effects related to specific program objectives (8). The approach is particularly useful to systematically account for various distributional impacts of concern to decision-makers. An expandable concept, program impact analysis can be modified to permit analysis of several policy options. Participant interests are stated along with performance variables corresponding to these interests. An analyst might identify economic costs and benefits to various participant groups associated with a range of food safety policies. Ranking on the basis of selected costs and benefits is possible. Research may identify behavioral incentives incorporated in various program designs in order to understand probable impacts upon firm and consumer decision-making. Behavioral incentives have ramifications for ultimate effectiveness, workability and impacts of programs. Uncertainty, organizational complexity and imperfect competition each color the economic decision context of food system participants. Satisficing behavior is the expected norm at each decision level.

Analysis of the impacts of food safety policies depends upon specification participant interests. Most chemical food safety problem situations include the following participant interests: interests in a chemical substance as product, as input, as contaminant and as policy problem. Mixed interests are possible. Participant interests in food safety regulatory policies, then, flow from economic interests in the regulated substance. Chemical product producers rationally evaluate and react to food safety policies on the basis of anticipated impacts on firm profitability; agricultural producers on the basis of impacts on production costs or product prices (plus impacts on firm operating autonomy); consumers on the basis of safety and cost; policy makers on the basis of cost-effectiveness and political acceptability.

Use of impact analysis in a systems framework can assist policy makers to identify alternative regulatory control points, control procedures, and predict probable firm and system response. Firm response to food safety policies directly influences the efficacy of the policy in achieving results intended to benefit consumers.

CONSTRAINTS AFFECTING SELECTION AND USE OF ANALYTICAL METHODS

Five sets of constraints influence selection and utility of analytical methodology: 1) executive orders; 2) statutory limitations; 3) information and conceptual limitations; 4) budgetary limitations, and 5) political realities

Executive Orders: Regulatory Impact Assessment

Executive orders issued by the current and two previous presidents have attempted to impose accountability for economic impacts of regulations on agencies. Hence, executive orders represent one set of constraints delimiting use of specific analytical tools. Executive orders have varied by analytical methods implied and decision rules required. President Ford required estimates of a policy's inflationary impact (E.O. 11821). President Carter required estimates of inflationary impacts plus a sort of cost-effectiveness evaluation (E.O. 12044); he mandated selection of the least costly policy alternative. Reagan (E.O. 12291) requires estimation of benefits in addition to costs, comparison of the two and use of a decision rule to maximize net social benefits (19).

Statutory Limitations

The decision context is directed by law for different categories of decisions. The Food Safety Council documents multiple uses of the word "safety" in food safety law. The Delaney Clause referring to food additives prohibits addition to food of substances shown to be carcinogenic. Under the law in this case, economic costs and benefits are not relevant.

Information and Conceptual Limitations

A third set of constraints limiting usefulness of some analytical techniques reflects the current state of the art in risk assessment, particularly risk associated with prolonged societal exposure to multiple low-level toxins in food. With regard to carcinogenesis, mutagenesis, teratogenesis, and genotoxicity, for example, most of the analytical techniques now used by physical scientists rely fundamentally upon plausible but highly uncertain and necessarily unproven extrapolations from bacterial screening tests or small sample high dose animal tests to human populations. Or, largely insensitive epidemiological studies are used. Assumptions are necessarily made: for example, that equivalent doses of a toxin (mg. toxin/kg. body weight/day) ingested by a mouse and a man will exert equivalent effects over the respective life spans (approximately two years for a mouse, 70 years for a man). This may or may not be true in any given instance. So at a very basic level in risk analysis, the degree of uncertainty is compelling.

Another required piece of information in assessing risk to a population, a sub-population or an individual is the degree of exposure to a hazard. If regulators are concerned about population exposure to a given contaminant in foods, they first need data on the foods likely to contain the contaminant (several may), and then the combinations and quantities of foods consumed. Food consumption surveys, based on dietary recall exist. Yet these are not entirely satisfactory for a number of reasons: the accuracy and completeness of people's recall is notoriously suspect; people are not aware of ingesting contaminants; contaminants are not uniformly distributed geographically; multiple contaminants may interact with uncertain effects; averages--average diet, average body weight, average susceptibility to risk, etc.--are not satisfactory in many cases, particularly if the intention is to protect the most sensitive members of society. Uncertainties at this level of determining exposure, then, also abound.

Another level of uncertainty influences the usefulness of certain analytical techniques: the consumer's demand for safety. In an economist's ideal world, consumers' valuation of "safety" or risk reduction would be measured through a market demonstration of willingness to pay for marginal units of risk reduction, (say, the amount consumers would pay to reduce the death rate by a specified amount). Problems with this were discussed above (12).

Budgetary Limitations

Budgetary limits in both the public and private sector obviously constrain the quality and quantity of safety or regulatory impact analysis sustainable. Ironically, the demand for analysis and budgetary limits appear to be growing in tandem. One result of this phenomenon in the public sector has been a slow-down in new protective regulations. Analytical demands on the private sector have the allocative impact of directing resources toward "defensive" research (justifying past R&D) rather than new innovation. The administration is currently supporting ways to expedite industry application for market approval in many cases. In other cases, agencies are not allocating funds to monitor markets.

To summarize a complex concern, the current economic climate is not promising of producing increased resources for data collection or analysis. It is a time, however, in which protective regulations including food safety regulations must be justified with more complete analysis than previously.

Political Limitations

Policy analysts conventionally agree that economic analysis or, by extension, risk analysis provides only one informational input for policymakers, and properly so. Other values and other priorities enter the picture. These factors, many of them political (and they may be internal or external to the agency), constrain the utility of analysis for decision-makers. It may not be the case that the analysis is not used; rather it may be weighted very lightly in relation to other factors.

A commonly cited example of political constraints to agency action is provided by the case of saccharin. Saccharin has been shown to be weakly carcinogenic in animal tests. Under the FFDCA, this fact should have resulted eventually in prohibition of the substance. (It was removed from the GRAS list in 1972, and a carcinogen cannot be approved as a food additive.)

Currently, however, Congress continues to permit use of saccharin in a variety of products when accompanied by warning labels. Realizing the political ramifications of a ban, FDA had delayed action long enough for Congress to act. Legislative action was taken in direct response to alarmed constituency groups fearful that this popular artificial sweetener would be withdrawn from the food supply with no substitute.

Conclusions

With respect to the problem of providing policy analysis to decisionmakers which is intellectually respectable and at the same time useful, a couple of observations can be made. By its nature, policy analysis in the area of safety research is fundamentally multidisciplinary. It must rely upon the best theory and experimental evidence available in biochemistry, toxicology, and a variety of physical sciences as well as economics. Policy analysts using these inputs must be fully cognizant that each discipline, along with analytical insights into the safety question, also contributes a level of uncertainty. The types and magnitude of uncertainty should be stated as part of the analysis whenever possible. In other words, decision-makers must be educated regarding the quality of the analysis and its potential biases.

Each of the analytical frameworks discussed above--cost benefit, cost-effectiveness, risk assessment and program impact analysis--has advantages and disadvantages for different purposes. While theoretically most complete from the standpoint of providing policy makers the opportunity to compare both benefits and costs of alternative programs, benefit-cost analysis in many instances requires substantially greater resources, both conceptually and data-wise than now exist in order to estimate benefits from the reduction of public health risks via food safety programs. Additionally, issues of the conceptually proper way to value human life remain, as do the problems inherent in reducing a multitude of distributional impacts to a single potentially misleading measure.

Given the difficulties of benefit estimation in the area of safety, the question arises whether it is preferrable to estimate economic costs associated with a program and compare these with reductions in risk or other qualitative measures of benefit. At this point it is provocative to consider Gresham's law of decision-making which, loosely put, is that quantified effects tend to dominate consideration (10). If this is indeed the case and the benefits of "protective" programs remain merely qualitative while quantitative costs abound, then the risks in not supplying credible estimates of benefits may swamp the virtues of prudence in this regard.

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DISCUSSION: THE CONSUMER AND FOOD

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It is good to see food issues, beyond nutritional labeling, under discussion at ACCI. Food issues topics received a good deal of consideration in the early years of ACCI, and merit our continuing attention.

The three papers presented deal, in various ways, with the benefits we seek from our food system. One questions some of the benefits or goals we have pursued, another looks at ways to assess the effectiveness of the means we have used to pursue our health-safety goals and the third focuses on the distribution of the benefits and costs of our food and agriculture policies.

Ann Christner has presented an provocative interpretation of the causes of some of our food habit changes. Both business and consumer education are indicted for the shifts toward more highly processed food products which are less nutritious and often less aesthetically satisfying but offer the advantage of time-savings and convenience.

Her analysis suggests a degree of omniscience among the early 20th century power elite which may, or may not have existed. Christner argues that the use of time-saving processed products was promoted to increase the housewives' leisure. This would, in turn, serve to ensure that new generations would be born and socialized for productive roles. Such a strategy has a long-term pay-off. If business interests really had a strategy, why didn't they settle for one with a quicker pay-off? Women could have been encouraged to enter into the labor force. This would have depressed the average wage thus lowering production costs, but would still have served to increase household incomes and buying power.

Consumer education must, I think, accept part of the blame for the "scientification of food" and the shift from other evaluative criteria to give chief emphasis to nutrient content. This emphasis was encouraged by the feeling that whatever was based in science was modern, while aesthetic factors (which are either hard to measure or unmeasurable, depending on your point of view) have less scientific basis. I'm afraid our concern, in consumer education, with academic acceptance and respectability have pushed us toward too narrow a definition of food's benefits. Along with our fear of the aesthetic, we've been afraid of looking at product use. "Use" is linked to the teaching of preparation skills and clearly lacks respectability at many college-level institutions. The neglect of product use in consumer education has had a number of unfortunate effects, including the neglect of safety issues.

Christner's closing question is a challenging one--are we teaching people how to achieve quality lives or are we teaching marketplace survival? We have, I think, been trapped by defining the objectives for consumer education, too narrowly.

Jean Kinsey has examined the benefits and the costs to consumers and farmers of our present crazy-quilt of agricultural policies. It is difficult to begin to evaluate the success of these policies since we are, purposely, a bit vague about our policy objectives.

Our vagueness about objectives is particularly evident in the commodity distribution/food stamp program. What began as an effort to dispose of excess supplies without threatening market prices has evolved into a welfare program, not only for stamp recipients but also for food retailers and food processors as well as for farmers. Perhaps the chief benefit of the program for recipients is to ensure that they participate more fully in the American way of life and enjoy the same nutritionally sub-optimal diet as the rest of the population.

The food stamp program's proponents emphasize its nutritional benefits. If we were to use cost-effectiveness measures, these benefits are costly. It might be far more effective to subsidize only the consumption of dairy products, fruits and vegetables. Political considerations, of course, make this infeasible.

Over the years the label on the issues Kinsey dealt with has evolved from farm policy to agricultural policy to food policy. This change is an indication of the growing number of groups involved in policy formation and in sharing the benefits and costs of programs. The interest groups involved include not only farmers and consumers, but also input manufacturers and sellers and food processors and retailers. The farm supply and food trade interests obviously have a bias toward demand-increasing policies and are opposed to those which restrict production.

While excess stocks of ag commodities are a tax burden, they are not without benefits for consumers. They do help stabilize prices. Because of the price inelasticity of demand for ag commodities, prices would have been far less stable in recent years if we had not had large stocks on hand. Wheat growers, in fact, have fought programs which would create buffer stocks, because they would dampen price run-ups in years of short crops.

Carol Kramer deals with the problems of conceptualizing costs and benefits for regulatory purposes. Her paper reminds us of the necessity of identifying what we seek from a program before we can begin to evaluate it.

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Kramer sagely notes the inherent bias of cost-benefit methods of dealing with risk. It is relatively easy to identify costs, but benefits not only are difficult to specify, they're also difficult to measure. There is a chronic risk of leaving out entire categories of benefits because of faulty conceptualization. And how are we to deal with even stickier problems such as interaction effects? For example, if we are dealing with the benefits of controlling bacterial contamination, how are we to deal with the fact that it is more beneficial to the aged and those in poor health than others since they are more suspectible to its effects?

These papers are a challenge to us to think both more deeply and more broadly about what we want from our food system. It appears we will have to clarify our objectives before we can begin to adequately evaluate its successes and its failures.

ECONOMETRIC ESTIMATION OF DYNAMIC CONSUMER DEMAND

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ABSTRACT

Theories of the dynamics of consumption present important estimation problems. First, their exploratory nature results in many competing hypotheses. The capacity for distinguishing among these hypotheses is largely empirical. Thus, statistical testing is necessary in composite and nonnested models. Second, the structures include proxy variables, lagged variables, and complex disturbance covariance structures. Conventional econometrics can be applied to address these problems, and for the alternative models the appropriate estimators have much in common.

INTRODUCTION

The primary purpose of this paper is to examine estimation and inferential problems associated with various theoretical specifications of dynamic demand systems. There have been several recent dynamic generalizations of the traditional static model of consumer demand. For example, various schemes have been proposed for reflecting habits and persistence in consumption patterns (see, e.g., [12]). Models which allow for disequilibrium in the short-run and long-run structures that are consistent with traditional economic theory have been developed and estimated by Anderson and Blundell [1, 2]. Attfield and Browning [4] use a completely different approach than those mentioned above to test the rational expectations hypothesis in a life cycle context. Other extensions to demand theory relate to refinements in intertemporal consumer models (e.g., [7, 15]), incorporation of risk and uncertainty elements into demand specifications (e.g., [14]), testing for endogeneity of prices and income [3, 6], modeling the demand for durables [16], and incorporating advertising effects into demand systems (see, e.g., [11]).

The present paper assesses the complexities that the various dynamic models generate for estimation and hypothesis testing. Although dynamic demand specifications may be very different, the estimation problems presented by the expressions required to implement the models are frequently quite similar. Evaluating the restrictions implied by the various dynamic models of consumer behavior, however, may require nonnested testing procedures. These and related econometric problems associated with the models of consumer demand dynamics will be addressed in the subsequent sections of our paper.

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DYNAMIC DEMAND SYSTEMS[3]

Persistence or Habits

Persistence or dynamics in consumption behavior can be represented structurally in terms of an economic hypothesis or by hypotheses not supported by the theory but introduced in the disturbances. The autocorrelation hypothesis is an example of the latter. The various habit persistence schemes are examples of the former. In the section on specific dynamic systems, a generalized dynamic specification integrating the two approaches will be developed in detail. However, since our emphasis is on estimation problems caused by dynamic consumer demand specifications, we will concentrate more on the econometric aspects than the theoretical underpinnings of the two approaches.

The estimation problems for dynamic models can be viewed as twofold. First, how can demand analysts discriminate between habit formation schemes that give rise to distributed lag models with lagged dependent (consumption) variables and static models with autoregressive errors, where the appropriately transformed model contains lagged dependent variables? Second, what is the proper estimation technique to use when lagged endogenous variables are present together with possible autoregressive-moving average (ARMA) disturbances? Solutions to these two related estimation and inference problems will be discussed in the sections on specific dynamic systems and estimation techniques.

Other Dynamic Complexities

Incorporating expectations into demand functions creates additional estimation problems. For instance, treating prices and income as endogenous variables present econometric difficulties associated with choices of admissible and efficient instruments. Attempting to model intertemporal trade-offs in consumer decisions produces theoretical complications as well, and the empirical models that tax available sample

[3] We are using the term "dynamic" as commonly employed in the demand literature. A multiperiod discrete demand system is truly dynamic if current utility depends on both current and past consumption levels, i.e., the consumer's objective function can be expressed as

$$\max \sum_{t=1}^{I} f(X_t, X_{t-1}, t)$$ (see, e.g., [13]).

information. Dealing with risk and uncertainty about product quality, prices and income, introduce additional problems. All of these dynamic components introduce complexities in estimation, requirements for new and constructed variables, different types of sample data, extended models, etc. In the sections on estimation techniques and tests of restrictions we will show that although the theoretical or conceptual basis for the dynamic specifications may be very different, the estimation and inferential problems presented by these various aspects of the models are indeed rather similar.

SPECIFIC DYNAMIC SYSTEMS

To examine the econometric problems for dynamic consumer demand systems more rigorously, the generalized dynamic demand model of Anderson and Blundell [1, 2] was chosen as the pedagogical vehicle. This choice of the general modeling framework was made for two reasons. First, several commonly used demand models are nested, or special cases of this more general specification. Second, the model has a great deal of intuitive appeal. In the case of the latter, the specification allows for short-run deviations from an equilibrium, and the usual homogeneity and Slutsky symmetry restrictions are imposed only on a long-run structure embedded in the more general dynamic formulation.

The Anderson-Blundell model can be expressed as

$$\Delta w_t = A\Delta X_t - B(w_{t-1} - \pi X_{t-1}) + \varepsilon_t \qquad (1)$$

where Δ represents the first difference operator, w_t is a vector of budget shares, X_t is a vector of prices and income, ε_t is the disturbance vector and A and B are short-run coefficient matrices[4]. The error term ε_t is assumed to be independently and identically distributed in time. Since the budget shares sum to one, the variance-covariance matrix for the error term is singular. This creates an estimation problem that can be easily overcome by arbitrarily deleting an equation. If autocorrelation does not exist, the maximum likelihood estimators are invariant to the equation deleted [5]. If autocorrelation is present, then the model must be transformed in the usual manner to purge the correlation in the residuals. Then, applying maximum likelihood estimation techniques to the transformed model yields estimators that are invariant to the equation deleted.

In equation (1), the long-run or the steady state structure, $w_{t-1} - \pi X_{t-1}$, is embedded in the more general first order dynamic structure. For example, $w_t = \pi X_t$ might represent the almost ideal demand system of Deaton and Muellbauer [9]. The usual restrictions of demand theory are only applied in this component of the model. No restrictions, since they are appropriate for the consumer theory, only the long-term or steady state, are imposed on the more general short-run structure.

For convenience, the system in (1) can be equivalently written as

$$W_t = CX_t + DX_{t-1} + EW_{t-1} + \varepsilon_t \qquad (2)$$

where $B = (I-E)$, $A = C$ and $\pi = B^{-1}(C + D)$. Several popular demand systems can be shown to be nested within the general dynamic model represented by equations (1) or (2). First, the static consumer demand model implies $D = E = 0$ in equation (2). Second, a static model with an autoregressive error process implies the restrictions $D = EC$ in equation (2). Third, a partial adjustment model implies that $D = 0$ in expression (2). Each of these special cases of the general dynamic expression can be tested using, for example, a likelihood ratio procedure.

The system in equation (2), with the nth row of ΔX_t and π and corresponding elements of w_t and ε_t deleted because of the singularity problems due to the adding up restriction, will be the focus of attention in discussing estimation problems in dynamic demand systems. In the remainder of the discussion, it will be assumed that this technical condition, permitting the arbitrary deletion of the equation for the nth commodity holds.

ESTIMATION TECHNIQUES

Estimation Likelihood Estimation

If $\varepsilon_t \sim N(0, \Sigma)$ in equation (1), that is, if the error term is assumed to be normally, independently, and identically distributed in time with mean zero and contemporaneous covariance matrix Σ, then the likelihood function expressed for a sample of size T is

$$L = (2\pi)^{-nT/2} \; |\Sigma \times I_T|^{-T/2} \exp \{-1/2 \; \Sigma \; [\Delta w_t - A\Delta X_t + B\,(w_{t-1} - \pi X_{t-1})] \; (\Sigma \times I)^{-1} [\Delta w_t - A\Delta X_t + B(w_{t-1} - \pi X_{t-1})]\}. \qquad (3)$$

where the symbol x represents the Kronecker product. Maximizing expression (3) can be shown to be equivalent to minimizing the generalized residual variance, $|V'V|T^{-1}$ where V'V is the reduced form residual moment matrix (see e.g., [10]). Under general conditions the full information maximum likelihood (FIML) estimators obtained from maximizing expression (3) are consistent, asymptotically efficient and normally distributed. There also exist other estimation procedures such as three-stage least squares that are asymptotically efficient under normality and assuming no prior information on the covariance matrix of the structural disturbances [10].

Little is known about the small sampling properties of estimators of models of the form (1), hence FIML estimators are attractive since they possess desirable large sampling properties. In

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[4] The system can be generalized to higher order differences, but for expository purposes we consider only the first order dynamic model.

addition, FIML estimates are useful in computing tests of hypotheses using the likelihood ratio, Wald and other procedures. It should be noted that, while other estimators may possess the same asymptotic properties, their numerical values may differ significantly in small samples. A major difficulty with using FIML is the problem with achieving convergence for even moderate size demand systems. However, in relatively small dynamic demand systems utilizing a program such as SHAZAM developed by White, FIML estimators are easy to obtain subject to the restrictions imposed by the model and the consumer demand theory.

In large dynamic demand systems, single-equation estimation methods can be used such as the instrumental variable technique to provide consistent, but not efficient estimators. For example, if lagged endogenous variables appear as explanatory variables, due either to persistence habit schemes or expectation formations, lagged prices and income can be used as instrumentals for these lagged dependent variables. Principal components of a matrix of lagged exogenous variables may also be used as effective instruments. In applied work, consistent starting values for the FIML method are frequently obtained from an initial instrumental variable estimation.

Special Estimation Problems

Intertemporal demand specifications, modeling the demand for durables, incorporating rational expectations into demand systems, etc. generate simultaneous dynamic systems. The systems resulting from these models can still be efficiently estimated by FIML. However, the estimation procedure becomes more complicated giving rise to two-stage estimation methods. For example, if rational expectations are incorporated into consumer demand systems, expressions with price expectations as functions of the expected values of the exogenous variables and errors terms are created (see e.g., [18]). While it is possible to estimate the stochastic processes generating the exogenous variables jointly with the parameters of the model with FIML methods, two-stage estimation procedures are often used. The generated variables emanating from the expectations schemes are estimated separately by, say, a Box-Jenkins procedure and then in the second stage these generated variables are substituted into the demand system and the remaining parameters are estimated by an appropriate, e.g., FIML, technique. This two- stage procedure is computationally attractive but yields losses in efficienty. In addition, the two-stage procedures also invalidate the straightforward likelihood function based tests of hypotheses. Corrective methods to overcome these problems in hypothesis testing have been developed (see e.g., [17]).

Alternative hypotheses can also produce consumer demand systems with endogenous prices and income. The more common of these are based on household production theories, endogenizing income, and the time series data on prices and quantity coming from equilibria of commodity markets. If prices and income are indeed jointly determined, then additional price determination, usually supply, equations and/or labor supply equations for income need to be added to complete the specification of the demand system. If this additional structure is not added to complete the models, the simultaneity gives rise to identification and misspecification problems.

TESTS OF RESTRICTIONS

Several asymptotically equivalent hypothesis tests are available for evaluating the restrictions of consumer theory. The Wald, likelihood ratio, and Lagrangian multiplier tests can be applied; but only the likelihood test will be discussed. Under appropriate regularity conditions $-2\ln L_o/L_A$ has an asymptotically chi-square distribution, $\chi^2(v)$, where v equals the number of linearly independent restrictions implied by the null hypothesis, L_o is the maximum value of the restricted likelihood function and L_A is the maximum value of the unrestricted likelihood function. An equivalent expression for the likelihood ratio statistic is $-2\ln \lambda = T\ln(|V'V|_o/|V'V|_A)$ where V'V is the reduced form residual moment matrix, i.e., minus two times the logarithm of the ratio of the maximum values of the unrestricted and restricted likelihood function equals the sample size times the logarithm of the difference between the determinant of the estimated restricted and unrestricted covariance matrices of the reduced form.

To illustrate how the LR test can be used in dynamic demand systems, consider the Anderson-Blundell model in equation (2). To distinguish between a dynamic structure and a static model with an appended autoregressive error term, the restriction D = EC must be evaluated. To proceed, estimate the system with and without the restriction imposed and calculate the associated maximum likelihood values for the restricted and unrestricted models. Then test this computed value against the appropriate critical χ^2 value. Other tests of parametric restrictions on equation (1) can be similarly performed.

Tests for causality, predeterminedness, and exogeneity in dynamic demand models are also possible. The three concepts differ, and Wu [19] has developed tests for each type of restriction. These tests have important implications for the possibilities for discriminating among alternative dynamic demand systems. A final problem to be discussed arises when one model is not a nested or special case of a more general or alternative form. For example, some habit formation schemes give use to demand systems that are not special cases of a partial adjustment demand system. And in the Anderson-Blundell model, the first difference model is not nested within the stochastic structure of expression (1). When this problem occurs, the usual likelihood ratio test or other asymptotically equivalent tests cannot be used. However, a recent but extensive literature has developed related to nonnested testing procedures applicable in these situations (see e.g., [8]).

CONCLUSIONS

Numerous and important advances have been made in modeling dynamic consumer behavior. With each new theoretical development, however, is associated a set of estimation and testing problems. Although the theoretical specifications differ widely, many of the estimators can be obtained using the familiar full information maximum likelihood approach. But as the models have become more complex, various other estimation procedures have been developed that yield consistent but not necessarily efficient estimators. The most complex of the situations discussed are those recognizing explicitly that in time series aggregate market data quantity prices and income all should be endogenous. The theory must be extended in these cases to provide structures for determining the equilibria. Micro foundations of supply and demand are then at issue and result in estimation problems which, while tractable, are highly complex. Discriminating among the alternative models in testing the various implied restrictions is important since, particularly for the more complex dynamic models, it is attractive to establish that the added structure is required given the available sample information. For most tests, the usual likelihood ratio or other asymptotically equivalent procedures can be employed. However, when models are nonnested, alternative nonnested testing procedures must be used. These procedures are generally less powerful and frequently produce classes of sets of models that are equally probable given the available data.

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ISSUES AND METHODOLOGIES FOR MODELING DEMAND FOR DURABLE GOODS

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ABSTRACT

The paper discusses the issues and methods for estimating the demand for durable goods. The paper presents the most recent development in modeling the joint decisions of appliance choices and uses in determining energy demand. An application of such a model illustrates the complexity and difficulty in analyzing the dynamic behavior of buying and using the durable goods.

INTRODUCTION

Every year, consumers allocate a substantial portion of their budget to purchase various durable goods. In 1983, U.S. consumers spent 280 billion dollars for durable goods which accounted for 13% of the total personal consumption expenditures in the National Income Account. Despite the significance of this expenditure category, there are relatively few empirical models for analyzing the demand for durable goods. This is, perhaps, due to the fact that, as Muellbauer [6] pointed out, "Modelling the demand for consumer durables is not one of the easiest topics in applied economics." In fact, it is one of the most difficult areas.

The difficulties in modeling durable good demand lies in the fact that the purchase of durable goods involves allocating the flows of budget resources over time. Furthermore, durable goods have a long life and therefore, a consumer's purchase of the good at a particular time may be as an addition or a replacement. Thus, there is a strong dynamic component in the demand for durable goods.

One important characteristic of the durable good is that consumers generally do not directly consume durable goods. Rather we use the durable goods to produce the goods and services directly useful to us. For example, consumers need warm air in the winter and cool air in the summer. To satisfy these demands, we would purchase a central air conditioner and use it to produce hot and cool air. In modeling durable goods, we often consider both their purchase and use. Also, it often requires other nondurable goods such as energy to operate a durable good. As such the demand for durable goods is also related to the demand for nondurable goods. Thus, as in the previous example, the demand for cool and hot air in the house would generate the demands for air conditioners and energy (such as electricity or natural gas).

In the literature, there are two general types of demand studies for durable goods. One deals only with the purchase of the durables and the other deals with its relation to the demand for other nondurables because of their usage.

The purposes of this paper are to review some important demand models for consumer durables and to investigate the role of durables in estimating energy demand. We focus on the methodologies for incorporating the dynamic behavior in empirical demand models.

STOCK ADJUSTMENT MODELS

The classical approach to deal with demand for durable goods is to incorporate a stock variable in the demand equation. This was done by Stone and Rowe [7] and Chow [3]. The basic idea in this approach is that consumers have a desirable stock of a durable good which as a result of utility maximization condition, can be expressed as a function of price and income. The actual purchase of a consumer durable is then affected by the current desired stock and the previous holding of the durable (with a specified rate of depreciation). Therefore, when the price of the durable and consumer income change, the consumer will adjust its desired stock. This stock adjustment will, in turn, affect the actual purchase of the durable. There are several variations in specifying the functional relationship between the purchase and stock adjustment.

In his study of automobile damand, Chow [3] derived and employed the following reduced from equation:

$$X_t = a_0 + a_1 P_t + a_2 Y_t + a_3 S_{t-1} + e_t \qquad (1)$$

where X_t is the number of cars purchased, P_t is price, Y_t is disposable personal income, and S_{t-1} is the stock of cars last year. In this specification, $a_3 = d-k$, where d is the depreciation rate and k is the stock adjustment coefficient. Therefore, by knowing d, k can be computed.

Equation (1) has incorporated the dynamic behavior through the stock adjustment. Thus, it captures both the short-run and the long-run responses. Specifically, the long-run price elasticity can be calculated as $(a_1P)/(kX)$ while the long-run income elasticity is $(a_2Y)/(kX)$.

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ROLE OF DURABLE GOODS IN SPECIFYING RESIDENTIAL ENERGY DEMAND

The 1973 and 1979 oil price shocks generated much interest among economists in estimating residential energy demand at different levels of geographic, fuel, and temporal aggregations. One common modeling strategy in the literature is to estimate the aggregate (as opposed to detailed end-use) residential demand for a particular fuel (such as fuel oil, natural gas, or electricity) at the national, state, or utility service area levels. It is well recognized that we, as consumers, can not adjust our energy use spontaneously to the fullest extent in response to changes in price and income. This is because in the short run, we are conditioned by the existing stock of appliances. It is only in the long run that we may achieve the desired level of appliances holding through new additions and replacement.

One common approach to incorporate this dynamic adjustment process is to follow the well known partial adjustment model or the flow adjustment model by Houthakker and Taylor [5]. These models generally lead to the presence of the lagged dependent variable in the reduced form equation. The most commonly adopted dynamic energy equation of this sort can be represented as:

$$\ln E = b_o + b_1 \ln E_{t-1} + b_2 \ln EP_t + b_3 \ln Y_t + b_4 \ln Z_t + U_t \qquad (2)$$

where E_t = aggregate residential consumption of an individual fuel in period t,
E_{t-1} = lagged dependent variable,
EP_t = fuel price,
Y_t = per capita personal income,
Z_t = other explanatory variables such as heating and cooling degree days,
U_t = the error term.

Equation (2) was widely applied in many studies of energy demand at the state or utility service area levels. Note that in Eq. (2) the short-run price and income elasticities are the estimated coefficients b_2 and b_3, respectively. The corresponding long-run elasticities are $b_2/(1-b_1)$ and $b_3/(1-b_1)$. The major econometric problem of estimating the parameters in Eq. (2) is the potential serial correlation resulting from the correlation between the lagged dependent variable and the error term. Also, the paramters are often estimated from pooling time-series and cross-sectional data. Thus, the error components model is the appropriate technique for estimation.

The specification of a dynamic energy demand such as Eq. (2) is nevertheless ad hoc because the role of durable goods was treated only implicitly in the partial adjustment process. In order to incorporate the durable appliances explicitely in the determination of electricity demand, Chern et al. [1] replaced the lagged dependent variables in Eq. (2) by a set of applicance related variables as

$$\ln E_t = C_o + C_1 \ln P_t + C_2 (\ln P_t)^2 + C_3 \ln P_t \cdot \ln Y_t + \sum_{j=4}^{7} C_j \ln P_t \cdot S_{j-3,\,t} + C_8 S_{1t} \cdot HDD_t + C_9 S_{2t} \cdot CDD_t + \sum_{k=10}^{11} C_k S_{k-7,t} + C_{12} \ln Y_t + C_{13} \ln CR_t + U_t \qquad (3)$$

where E = quantity of residential sales of electricity,
P = real average electricity price,
Y = real per capita personal income,
HDD = heating degree-days,
CDD = cooling degree days,
S_1 = saturation level of electric space heating equipment,
S_2 = saturation level of air-conditioners,
S_3 = saturation level of electric water heaters,
S_4 = saturation level of electric clothes dryers,
CR = number of residential customers.

In this model, major durable appliances were represented by the set of appliance saturation variables which were defined as % of households having the particular appliance. In essence, these are stock variables. Chern et al [1] estimated Eq. (3) with two-stage least squares (2SLS) and three-stage least squares (3SLS) using state-level data (thus, there were state dummy variables also).

The simultaneous equations model was necessary because the electricty price was treated as a endogenous variable due to the differential block-rate structure. Note also that Eq. (3) is really a varying elasticity model which allows demand elasticities to vary from observation to observation (or specifically, from state to state).

Electricity demand model in Eq. (3) is a short-run demand model because the stock of appliances is fixed. It is a conditional demand model given appliance saturation levels. Therefore, in order to estimate long-run electricity demand, we need to model the saturation levels of electric appliances. Since consumers select energy related appliances by fuel type, the choice of appliance may be treated as the choice of fuel. (Of course, one may consider the choice of different types of appliance within a fuel category such as different electric heating systems). One of such aggregate fuel choice models is a generalized appliance choice model which can be expressed for a particular end-use as

$$\ln \left(\frac{s_{it}}{s_{jt}}\right) = d_o + d_1 \ln P_{it} + d_2 \ln P_{jt} + d_3 \ln P_{kt} + d_4 \ln Y_t + d_5 \ln \left(\frac{s_{i,t-1}}{s_{j,t-i}}\right) + U_t \qquad (4)$$

where S_i = saturation level (%) or market share of fuel i in period t,
P_i = price of fuel i.

and all other variables were defined previously.

Equation (4) follows the partial adjustment hypothesis and therefore, it is again an ad hoc procedure for handling the dynamic behavior of the choice of durables.

Unfortunately, the estimation of Eq. (4) can not be implemented because of lack of continuous time-series on appliance saturation. The state-level data from the Bureau of the Census were available only for 1960, 1970, and 1980. Note that for estimating Eq. (3), Chern et al. [1] generated appliance saturation data for intervening years but they are not real data.

JOINT DETERMINATION OF THE DEMAND FOR APPLIANCES AND THE DEMAND FOR ELECTRICITY

The methodologies presented in the previous sections are ad hoc because demand specifications for durable goods are not derived directly from maximizing a well defined direct or indirect utility function. In the case of energy demand, one may argue that the decisions for the purchase of an appliance and for the utilization of the appliance are jointly determined. Therefore, the parameters in the short-run utilization equation and the long-run appliance choice equation may be derived from the same direct or indirect utility function. One such model was developed by Dubin and McFadden [4]. They developed a model for estimating (1) space and water heating choices and (2) annual electricity demand conditioned on space and heating choices. In modeling space and water heating choices, they made several assumptions to justify appliance choices as a contemporaneous decision. Specifically, they assumed that real capital costs of heating systems evolve only slowly and future energy prices equaled to 1975 level. These assumptions were necessary in order (1) to simplify the theoretical model and (2) to facilitate the model estimation with micro household survey data which are typically available as a one time only cross-sectional data base. In fact, a dynamic appliance choice model derivable from the utility maximization conditions remains to be developed. It is not certain whether or not current data bases are sufficiently rich for estimating such a model (we need time-series of cross-sectional data or longitudinal data).

In the Dubin-McFadden model, the portfolio choice probabilities for electric space and water heating have a non linear multinominal logit form and are a function of annual operating cost, capital cost, income, electricity price, gas price, annual typical electric demand, annual typical natural gas demand, and gas availability index. The unit electricity consumption equation is also nonlinear and is a function of cost and price variables as in the choice equations and others variables like household size, number of rooms, and home ownership etc. Although, they developed the choice and unit demand equations jointly, they estimated the choice equations with the maximum likelihood method, and the demand equation by alternative consistent estimators.

The Dubin-McFadden model represents the most rigorous treatment of the choice of durable appliances and their usage in analyzing energy (or electricity) demand. However, the model requires extensive micro-level data base at the household level (just like other discrete choice models). Further these microsimulation models are often not adequate for forecasting aggregate energy (or electricity) demand. In order to fulfill the need to forecast aggregate electricity demand for the Nuclear Regulatory Commission, Chern and Just [2] developed a durable demand-utilization model which can be estimated on the basis of available aggregate data (at the state level). Chern and just employed the following indirect utility function with an assumption of strong separability:

$$V = V_o + \sum_j V_j \qquad (5)$$

Where V_o = a function reflecting utility from all other groups of commodities,
V_j = utility function for household good j (such as warm air) produced by alternative fuels.

Furthermore, they postulated the following specific functional form:

$$V_j = g_j \left\{ \left[M + \sum_i I_j^i \left(-K_j^i + r_{oj} + r_{1j} P_i + r_{3j} Z_j + U_j \right) \right] e^{-\sum_i I_j^i P_i r_{2j}} + \sum_i I_j^i W_j^i \right\} \qquad (6)$$

where g_j = any monotonically increasing function,

P_i = deflated price of household fuel i corrected for efficiency,
K_j^i = deflated annualized fixed cost associated with ownership and maintenance of the durable using fuel i to produce household good j,
Z_j = representative exogenous variable which affects the demand for household good j, i.e., heating degree days, urban residence, etc.,
I_j^i = Indicator of ownership of the durable using fuel i to produce household good j,
M = deflated per household disposable income,
U_j = unobserved terms and random short-run preferences for household good j,
W_j^i = unobserved terms and random long-term preferences for fuel type i in producing household good j.
r_{ij} = parameters to be estimated.

From Eq. (6), one can derive the electricity use equation using the Roy's identity and the probability of fuel choice following a generalized extreme value distribution assumed for W^i_j. Chern and Just further aggregated these results for individual consumers to the market aggregate. The empirical model consists of two sets of structural equations. The first is a set of appliance choice probabilities expressed in terms of the saturation of fuels by end-use as:

$$\ln \frac{S^i_j}{S^k_j} = (M-k^i_j+r_{oj}+r_{1j}P_i+r_{3j}Z_j)\, e^{-r_{2j}P_i} -(M-K^k_j+r_{oj}+r_{1j}P_k+r_{3j}\, Z_j)e^{-r_{2j}P_k} + U_{ijk} \quad (7)$$

where S^i_j = saturation (or market share) of fuel j for end-use i, and

$$U_{ikj} = U_j\,(e^{-r_{2j}P_i} - e^{-r_{2j}P_k}).$$

The market level use fuel equation is expressed as:

$$X_i = \sum_{j=1}^{J} S^i_j \left[\gamma_{oj}\gamma_{2j}-\gamma_{1j}+\gamma_{1j}\gamma_{2j}P_i+\gamma_{2j}\left(M-k^i_j\right) +\gamma_{3j}\gamma_{2j}Z_j+U_i\right] \quad (8)$$

where X_i = average use of fuel i per household,

and $U_i = \sum_{j=i}^{J} S^i_j\, r_{2j}U_j$

Due to the complicated structure of the error terms, the hetroscedasticity and contemporaneous convariance must be considered in efficient estimation. Note also that the same parameters appear in determining the fuel choices in Eq. (7) and fuel use in Eq. (8). Efficiency can not be attained unless the information relating to these parameters from both equations is utilized.

AN APPLICATION

To demonstrate the methodology developed by Chern and Just, a simultaneous equations model is developed to use annual electricity demand data from the 48 continuous states for 1955-1976. Appliance saturation data representing the proportions of electricity customers owning electric space heating equipment, air conditioners, and electric hot water heater are available for 1960 and 1970 only. Thus, the fuel choice or saturation equations are estimated with data for these two years (96 observations). For the usage equation, data on appliance saturations for the intervening years were derived from the logistic curve fitted with data for 1960 and 1970.

Since there are only three major electric appliances considered in the analysis, the model consists of the following four equations:

(1) Electricity usage equation similar to Eq. (8).

(2) Saturation equation for space heating (j = 1) similar to Eq. (7). The alternative fuel refers to all other fuels (natural gas and fuel oil combined). Therefore, the dependent variable in Eq. (7) can be expressed as $\ln [S_1/(1-S_1)]$. In this equation, the variable Z_j is heating degree days.

(3) Saturation equation for air conditioning (j = 2). Since the alternative is no air conditioning, the dependent variable can also be expressed as $\ln [(S_2/(1-S_2)]$. In this equation, the variable Z_j is cooling degree days.

(4) Saturation equation for water heating (j = 3), similar to the one for space heating.

Since we combine all alternative fuels to electricity into a composite aggregate, for each of the three end uses, only one fuel choice equation is needed. This is, of course, a simplification of the real world situation because consumers can only choose either of two fuel groups rather than three.

The estimation of this system of the four nonlinear equations follows the following four steps:

Step 1: The instruments are developed by ordinary least squares (OLS) for electricity price and the price of alternative fuels. These price variables are treated as endogenous variables in the model.

Step 2: The usage equation, Eq. (8), is estimated by OLS with instruments obtained from Step 1.

Step 3: The four structural equations are stacked together. All appropriate constraints across equations are imposed. The resulting nonlinear system is estimated by nonlinear least squares, using the parameter estimates from Step 2 as the starting values. (The software package, SAS is used for estimation).

Step 4: The residuals obtained from Step 3 are used to calculate the variances for each structural equation. The appropriate weights are then computed. These processes were iterated by performing weighted nonlinear least squares until the estimated parameters converged.

The procedure outlined above produce the consistent estimator but not the most efficient one. Further gain in efficiency is possible if one more step is taken to consider the correlations across equations. This additional step was not performed because it involves developing a rather messy convariance matrix of order 1344.

There are 12 parameters to be estimated, and they are r_o, r_{o1}, r_{o2}, r_{o3}, r_{11}, r_{12}, r_{13}, r_{21}, r_{22}, r_{23}, r_{31}, r_{32}. The parameter r_o is the constant term added to the usage equation to