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Developing Policy Relevant Agrifood Models

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The opportunities and challenges of incorporating accurate policy representations into institutional partial equilibrium commodity models were investigated. Six issues are raised: commodity space definition, vertical linkages, assessing market power, the changing nature of government support, trade policy, and data requirements. The importance of product attributes and different approaches to modeling product differentiation are considered. A case study of food safety is used to bring together the major issues. Although institutional commodity models still have a role to play, we advocate the use of smaller idiosyncratic models to address many of the relevant policy questions in a rapidly changing sector.

Key Words: commodity models, food safety, policy, product attributes

JEL Classifications: F13, Q17, Q18

Large econometric partial equilibrium models are a mainstay of forecasting and policy analysis at national agriculture departments, international organizations, and some policy centers associated with universities. These models are large, require significant amounts of labor and data to update and maintain, and are not particularly flexible with respect to the policy issues that they can address. Essentially, the current models are designed to evaluate commodity-specific "farm programs" at the primary level. Given the rapid changes that are taking place within the agrifood sector, are these models capable of addressing current and evolving policy questions? What are the opportunities and limitations for incorporating more accurate representations in these models? Is a one-size-fits-all model appropriate for analyzing every policy issue or should smaller more flexible models be customized to the issue at hand? It is to these questions that the present article is addressed; however, it is far easier to raise questions than it is to identify solutions.

The nature of government policies is evolving over time. Commodity-specific price instruments have been changed into direct income transfers to producers. Policymakers are increasingly concerned with food safety, environmental degradation, rural development, new industrial uses for agricultural products, biotechnology, and the recurring issue of increased concentration and market power in the processing, wholesaling, and retailing sectors.

Not only have agricultural policies changed, but so has the nature of the products that are being produced and traded—products with unique attributes have taken on much greater importance than they did historically. These attributes often relate to how the product is produced and are as broad ranging as, is the production process environmentally

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friendly; is the food processor socially responsible; and are there potential long-term health problems associated with consumption of the good. The changing nature of consumer tastes, and the production of agricultural commodities with different attributes has resulted in a marketplace filled with differentiated products where a single homogeneous "commodity" used to dominate. With product differentiation the potential to exercise market power throughout the value chain is enhanced, as is the potential for primary producers to earn price premiums for differentiated output. For commodity models to have relevance, they have to account for product differentiation and economically important niche markets.

In the next section, the role of commodity models in a changing policy environment is explored. The challenges facing policymakers are discussed, and six issues that need to be considered in building relevant policy models are presented. Many of the concerns of policymakers relate to the attributes of agrifood products. Although consumers have always been faced with different qualities of products, policy makers' attention is increasingly focused on consumer-driven agriculture and product differentiation. The third section discusses how differentiated products are modeled and how attributes are measured. The fourth section uses food safety as a case study that brings together the issues of product attributes and differentiation, the importance of vertical market linkages, trade policy, and market power.

Issues in Constructing Relevant Policy Models

Agricultural policy makers and senior bureaucrats are involved in a sector that is perceived to be shrinking. Although farming accounts for less than 1% of U.S. gross domestic product, the entire food and fiber system—spanning farm inputs, agricultural production, processing, trade, and ancillary services—accounts for 16% of gross domestic product (U.S. Department of Agriculture). Increasingly, the policy focus is on the broader definition of the agrifood sector rather than being confined to commodity programs. Most of the growth in the agrifood sector is beyond the farm gate, which has captured policymakers' attention.

Trade is an increasingly important component of the demand for agrifood products and has always been viewed as an engine of growth. Low- and medium-income countries are the markets with the most potential for growth in food consumption. Although these markets will consume more bulk commodities, most of the export growth will come from trading the higher-value and consumer-ready products that already dominate agrifood trade. Unlike bulk commodities, higher-valued products are differentiated products, and trade is often two-way between countries with similar resource endowments. Institutional policy models must account for the nature of this trade in forecasting and in determining the gains from trade.

There is also a potential for growth, both domestically and through exports, with nontraditional products. For example, specialty chemicals derived from plants, ethanol and biofuels, nutraceuticals, and industrial adhesives all represent nontraditional uses of agricultural commodities. The attributes necessary to produce these products may differentiate the primary agricultural input for these nontraditional products from other bulk commodities.

Consumers expect the food system to deliver more—greater variety, improved safety and nutrition, greater convenience, and fewer environmental effects. The response of the food-processing sector to the demand for differentiated products has been better coordination throughout the supply chain such that consumer signals are transmitted more effectively. This results in a wide variety of marketing arrangements with more (production and marketing) contracts between individual producers and processors and increased vertical coordination (U.S. Department of Agriculture). Increased concentration and thinning cash markets also raise concerns about the potential abuse of market power and the problems associated with structural change.

Policymakers are being forced to understand more complex markets, and they want models that will aid in explaining the changes that are happening, resolving policy issues, and predicting future changes. The focus of the modeling effort has to encompass food processing and other postfarm activities. Policymakers are concerned with vertical relationships along the supply chain. Relevant models must not only account for cross-commodity effects but also for relationships between different levels of the supply chain. As decisions are internalized within a few integrated entities, the concept of a market becomes blurred; as a result, it is extremely difficult to model this behavior. As a consequence, the economic information required by senior decision makers is broad and varied, and it seems unlikely one model can serve all purposes. The future of policy models, small or large, depends on their ability to address the market effects associated with this multitude of issues.

There are a few large multicommodity, multicountry, partial equilibrium trade models (e.g., FAPRI, AGLINK, and ESIM) that are regularly used for policy analysis and forecasting.[1] In most cases, these models have a long history, and the use of the models is restricted to members of the institutions that own them. One way to judge whether a model is relevant is to ask, "would it be built in the same manner if the research institution were to start from scratch?" We suspect that, in many cases, the answer would be no.

The first decision in building a new model is whether it should be a partial or general equilibrium model. Partial equilibrium models are best used when the effects of the policy change are largely limited to the sector in question.[2] The strength of the current institutional commodity models is their broad commodity coverage, within agriculture, across many countries and regions. The disaggregation that is possible in a partial equilibrium model is typically greater than in a general equilibrium model. Partial equilibrium models are capable of addressing linkages among several levels of the market, but the coverage is typically unprocessed or first-stage processed agricultural products (van Tongeren, van Meijl, and Surry).

Often it is possible to introduce more institutional detail into partial equilibrium models than in general equilibrium models. The incorporation of policies in general equilibrium models typically involves using price wedges in price-linkage equations for various agents in the economy. The direct representation of policies through the incorporation of the actual policy mechanism is the preferred approach. Because the structure of partial equilibrium models is more flexible, it is, at least conceptually, easier to incorporate these policy mechanisms in partial equilibrium models. Therefore, we will only focus on the development of policy-relevant partial equilibrium models, although the issues raised are equally important for general equilibrium models.

Any institution that decides to build a new partial equilibrium policy model will have to confront six issues. The first issue is how to define the relevant commodity space when food products are becoming more heterogonous? Second, the model must be designed to account for vertical relationships through multiple levels of the supply chain. Third, it is important to address the issue of market power in an increasingly concentrated sector. Fourth, the changing nature of government support must be accounted for, and the model must be flexible enough to accommodate frequent changes. Fifth, because trade is such an important component of North American agriculture, it is vital that the model be able to measure trade flows and the effect of border measures. Sixth, data limitations ultimately determine the type of model that can be constructed and the available data puts limits on what can be done. Each of these six issues for building relevant policy models is now discussed in turn.

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[1] See van Tongeren, van Meijl, and Surry for a review and assessment of global partial equilibrium models.

[2] For the spillover/feedback effects to be insignificant upstream factor supply should be perfectly elastic and downstream final demand should be perfectly elastic.

Defining the Commodity Space with Heterogeneous Products

The definition of a commodity/product is the key issue in developing a relevant institutional model, and this issue cuts across all other considerations discussed in the present article. When a new attribute—for example, a genetic modification or a particular processing method—is introduced for a traditional commodity, is there one product or two? The answer depends on product differentiation, which is typically thought of as a demand-side consideration (and will be considered in detail below), but it has supply-side implications as well. For example, will the new product involve complicated externalities, as in the case of genetically modified products? What are the trade implications for the new product and for the original product? The decision to model a separate market depends on these considerations and others.

There are problems with accounting for entirely new products as well. Is there a commercial market for the product or is a government subsidy required? If a subsidy is required, how large is the subsidy and what are its welfare effects? What should be the definition of the market for new industrial or final consumption products? Should an entirely separate market be defined or is there a commodity market where the new product could be included with an appropriate adjustment for a price premium? If so, how should the price premium be measured? For commodities with industrial uses, are there sufficient incentives for farmers to grow the product to industrial specifications? Does a commodity with a new industrial use belong in a separate market or can it be modeled as belonging in the traditional market with a premium added for the industrial use? The relevant literature discussing how new products might be introduced into a policy model is reviewed below.

The Role of Vertical Relationships

It is as important to account for the relationships between various levels of a supply chain as it is to account for cross-commodity effects. For new products, how are the benefits distributed through the supply chain? For new regulations designed to enhance food safety or to change the quality characteristics of products, how are the costs distributed through the supply chain? General equilibrium models have the capacity to account for these vertical linkages, because the model accounts for all factor and product markets in the economy. However, problems with aggregation limit the usefulness of general equilibrium models to address some of the questions associated with vertical markets, and it may be desirable to use a somewhat more ad hoc approach.

One alternative to a complete general equilibrium model draws on the work of Muth, Floyd, and Gardner and accounts for equilibrium across several product and factor markets. This equilibrium displacement technique shares many features with general equilibrium modeling but does not account for the feedback between factor incomes and product demand. Equilibrium displacement models use multimarket equilibrium elasticities to determine the incidence of policies across input and output markets.[3] The ability to calibrate these models, with minimal data on prices, quantities, and elasticities, allows the researcher to examine the relationships between several levels of a supply chain. Equilibrium displacement models can be derived using either the homogenous or differentiated product assumption. James and Alston incorporated quality variation (vertical differentiation) in an equilibrium displacement model with high and low quality goods where there is substitution between the two qualities in terms of both supply and demand.

Market Power

Consideration of imperfectly competitive market structures opens up a Pandora's box of theoretical problems. Nonetheless, an increasing

[3] A typical model based on differentiating a system of logarithmic equations including production functions, first-order conditions, factor supply, and commodity demand, then calibrating them with share and elasticity parameters and solving them for the multimarket equilibrium elasticities.

number of policy questions require consideration of imperfect competition, because agrifood products are becoming increasingly differentiated and contracting and vertical integration are more frequent. Having said this, what is the nature of the market power—oligopoly, oligopsony, or both? Who holds the market power: processors, retailers or both? Sexton et al. provided a summary of the new industrial organization literature, in an agrifood context, and illustrated that the gains from trade and the distribution of welfare gains are highly dependent on market power assumptions. The incorporation of imperfect competition into computable general equilibrium models takes a number of forms: constant marginal costs plus large fixed costs and monopolistic competition or oligopolistic behavior with Cournot or Bertrand strategy with a differentiated product (Hoffmann). However, general equilibrium models with an imperfectly competitive structure are not that common. This is not surprising, because representations of small-group strategic interaction may not be appropriate in a highly aggregated model.

Structure/conduct/performance studies have been used extensively to measure food-processor oligopoly and oligopsony behavior (Sexton). However, this approach is not particularly useful in terms of incorporating information on market power into a general market model. The new-empirical-industrial-organization (NEIO) approach uses explicit economic models with final demand, input demand, and product supply (marginal cost) to measure market power, and this design can be incorporated into a model of broader market interactions. These models do not impose a particular type of oligopolistic/oligopsonistic behavior (e.g., Cournot) but allow the data to determine the type of conduct and allow the researcher to test for alternative types of market conduct. The NEIO models are capable of measuring market power at multiple levels of the food chain (Sexton et al.).

Data considerations contribute to the problems of measuring market power. Typically, NEIO studies are conducted with data for aggregate industries at the national level. The inability to define relevant markets and aggregation problems creates a bias against finding market power (Sexton). Holloway (1991) used an equilibrium displacement model to extend the Gardner's model to test for market conduct. This approach may prove useful for incorporating market power into relevant market models.

The Changing Nature of Government Support

The U.S. Federal Agricultural Improvement and Reform Act of 1996 changed the nature of how support was provided to farmers in the United States.[4] The method of transfer changed from market-based interventions to direct payments. These transfers are based on fixed criteria, including historic yields and area. Because producers cannot affect the size of the government payout, they should only base their production decisions on market signals, not government payments. However, these direct transfers can still influence production decisions through indirect channels. For instance, if producers are risk averse and they receive a direct transfer, then the wealth effect could reduce their risk aversion and affect their production decisions. Likewise, if a producer faces a credit constraint, a wealth transfer could change his investment decisions, because the credit constraint is relaxed. Although current payments are not tied to current production, there is a potential expectations effect, where the producer may attempt to expand current output in order to increase the base on which future payments may be determined. This behavior was rewarded in the United States in 2002, when the Farm Security and Rural Investment Act was passed and allowed producers to update their base areas. Finally, even though direct payments are fixed, they can affect entry and exit decisions. The movement away from market price supports

[4] The 2002 Farm Bill shifted policy back to more conventional commodity programs. However, direct payments remain a large component of the legislation. Even the countercyclical payments, which are reminiscent of deficiency payments, are based on fixed criteria of historic yields and area.

and commodity-specific payments is a worldwide phenomenon. According to the Organization for Economic Cooperation and Development (OECD 2003), in the 1986–1988 period, market price supports accounted for 62% of the total producer support estimate. By 2002, market price supports accounted for 47% of the total producer support estimate and were 20% lower, in nominal terms, than in 1986–1988. Payments based on either an area/headage or historical basis increased by 166% between 1986–1988 and 2002.

Capturing all of these effects in one model is, to say the least, problematic. There are multiple mechanisms through which policy measures may affect farmers' production decisions. Nonetheless, certain modifications would make agrifood models more relevant in assessing the effects of direct payments. The incorporation of risk and risk preferences into supply response would help address some issues associated with wealth effects. Models that include factor markets are more appropriate for assessing production decisions. Input subsidies (taxes) are also better addressed through the factor market. Furthermore, because most government transfers tend to become capitalized in land values, including factor markets will account for this effect. Moreover, as agricultural policy changes to focus on the protection of the environment and food safety, government regulations have the potential to raise producers' costs. If the government provides compensation, it is desirable to model the effects of these payments on production decisions, and this should be done through the factor market. Finally, addressing investment decisions explicitly should help explain the effects of direct payments on production decisions.

Trade Policy

Modeling trade flows has always been problematic, but now the major issue is how to account for intra-industry (where a country both imports and exports the same good) trade in consumer-ready products. Most commodity models are net trade models, so a country is either a net importer or net exporter of the commodity in question. Net trade models have tended to be used to explain trade in a limited number of homogeneous raw commodities, but, increasingly, trade is in differentiated processed products and consumer-ready goods (Gehlhar and Coyle). Intra-industry trade is important even at high levels of disaggregation, with countries reporting imports and exports of the same good (van Tongeren, van Meijl, and Surry). The Armington specification is the most popular method to handle trade in differentiated products, but, at the same time, it is highly restrictive (Carter and Alston).

Many policy disputes and policy instruments are bilateral in nature. Trade policy is not as simple as measuring tariffs and quotas. Different tariffs are applied to imports from different regions because of preferential access. Bound tariffs (maximum tariff level commitments made to the World Trade Organization) are not always identical to the tariffs that are applied. Grant and Meilke found that the gap between bound and applied tariffs in the world's major wheat importing countries equaled 62 percentage points after the Uruguay Round tariff cuts were implemented. Partial equilibrium commodity models often use tariff equivalents to measure quantitative restrictions. Alternatively, imports can be treated as fixed to represent a quota. However, quotas are not always binding, so the tariff equivalent should be zero. A policy shock may cause a nonbinding quota to bind. Tariff rate quotas are multitiered tariffs that can have the characteristics of both tariffs and quotas.[5] In some instances where foreign companies make direct investments in the domestic market, imports may be replaced by domestic sales of the affiliate of the foreign company. As trade barriers fall, the location of production of certain foods will move across the globe to where the raw inputs and other factors are the cheapest. This behavior cannot be described with a nonspatial net trade model.

[5] A number of partial and general equilibrium models have used complementary slackness conditions to explicitly model tariffs and quotas.

Data Requirements

Data requirements are determined by the level of disaggregation of the market under consideration and the theoretical structure of the model (homogenous or heterogeneous, competitive or noncompetitive, bilateral or net trade flows, etc.). Many of the new products that are being considered should be modeled individually. However, there is frequently insufficient data, in terms of prices and quantities, to model a new market. Even if the new product is simply an innovation of an existing product, with an improvement in some attribute, and can be accommodated with an existing commodity model, there may be insufficient information on price premiums to properly identify the demand structure for the product with the new attribute. More comprehensive and regular updates of available data sets would improve the timeliness and relevance of policy analysis.

In many cases, the models are not estimated econometrically but are calibrated to baseline data. The advantage of calibration is that the process is not data intensive, exploits theoretical restrictions, and is consistent with benchmark data. The calibration exercise requires information on budget or cost shares, elasticities of substitution and possibility price, and income elasticities and supply elasticities. Calibrated models need updating to stay current, but so do the parameters of models that were initially estimated with econometrics.

Summary

The consideration of the above six issues is crucial in developing relevant policy models, even though it may not be feasible to address all of the issues in one model. Cutting across all six issues is the proper definition of a product. In the next section, we elaborate on the importance of product attributes and the different ways to handle new or highly differentiated products in a market model. Then, a case study of food safety regulations is used to illustrate how the six modeling issues influence the choice of a proper modeling framework.

Product Differentiation and The Role of Attributes

Model builders face a number of problems in their attempts to carry out relevant policy analysis in a changing agrifood sector. A recurring problem is that they typically treat agricultural products as homogenous, when these products are rapidly becoming more differentiated. Product differentiation is partially driven by the consumer's desire for specific product attributes. These attributes may include safety, convenience, quality, location, health and nutrition, ethical issues, and process attributes such as environmental quality, animal welfare, and genetic modification. This section addresses the question of how product differentiation can be addressed in an institutional model and how to model and measure product attributes.

Since the 1920s, product differentiation has been a subject of interest to economists. Goods are almost always differentiated by some characteristic: quality, location, time, availability, consumer's information, and so on. Given the broad number of methods to distinguish products, it is convenient to categorize the different ways that consumers differentiate between goods based on a small subset of characteristics and the associated preferences. *Horizontally* differentiated products vary in certain product characteristics that appeal to distinct groups of consumers. With *vertical* differentiation, goods with the same characteristics differ in quality, so that all consumers prefer the higher quality products.

There are two different approaches to horizontal differentiation. One approach goes back to Chamberlin, where the consumers prefer diversity and utility is an increasing function of the number of varieties (Dixit and Stiglitz; Spence). In the second approach, associated with Hotelling, consumer heterogeneity is due to different locations or tastes. Although Hotelling's approach referred to the physical location of the consumer, location can also mean the distance between the brand characteristic that a particular consumer views as ideal and the characteristics of the brand actually purchased (Lancaster 1979).

So far, the discussion of product differentiation has focused on endogenous factors, but differentiation can also be determined exogenously. The best-known case of an exogenously differentiated product is one that is differentiated by country of origin (Armington). This type of model is frequently used to account for intra-industry trade, but it is not specific about the reasons why products differ across countries.

Endogenous product differentiation is of more use for determining the effect of varying product attributes. However, it is not always practical to distinguish between vertical and horizontal product differentiation. Furthermore, neither the neo-Chamberlin nor the neo-Hotelling framework is superior in all settings. Because horizontal differentiation refers to the concept of product variety rather than quality, it is more useful to analyze issues such as brand loyalty, rather than issues such as food safety, which is more appropriately dealt with in a vertically differentiated model.

Describing consumer behavior in terms of choosing between bundles of attributes, or characteristics, also has a long history in economics going back to Houthakker and Theil. Houthakker described a good in terms of quantity and quality, where the consumer selects both the quantity and characteristics of the good. Goods with different characteristics were treated as the same good but as having different qualities. The price of each good is determined by the amount of characteristics chosen.

Lancaster (1966, 1979) developed another version of a characteristics model. He viewed goods as bundles of characteristics and argued that utility is derived from these characteristics. Consumers maximize utility, defined in terms of characteristics, subject to a budget constraint defined in terms of goods. Because utility and the budget constraint are defined in different units, Lancaster introduced a technical relationship between the quantity of a product and the attributes that it possesses. This theoretical model is the conceptual basis for a number of different approaches that attempt to measure attributes.

So how are the values of these attributes measured? Very roughly, the approaches to measuring attributes can be classified as revealed preference (based on actual market behavior) or stated preference (based on hypothetical scenarios). Probably the best-known revealed preference approach to measure the value of attributes is hedonic pricing (Griliches). Rosen cautioned that hedonic pricing involves a problem where neither the demand for nor the supply of attributes is identified. He formulated a theory of hedonic prices in a spatial equilibrium framework where consumer and producer decisions are determined in characteristics space. Rosen explicitly modeled the market equilibrium conditions and provided a practical approach to identify compensated demand and supply functions that could be estimated by econometric methods.

The value of an attribute is frequently measured with a qualitative response model.[6] As above, utility is a function of attributes or characteristics. These models determine the probability that the utility of a particular alternative exceeds the utility of other alternatives. The choice in these models is between discrete alternatives and the dependant variable is the probability of choosing a particular alternative. The choice can either be between two (binomial) or more (multinomial) alternatives. Given that the dependent variable is limited to a specific range of values (between zero and one for a probability), special econometric techniques must be used to estimate the qualitative response model.

Much of the recent research on qualitative measures of attributes uses random-utility models. In this approach, utility is the sum of systematic and random components. The random component reflects the researcher's uncertainty about the choice. Although this approach also determines the probability that the utility of one alternative exceeds the utility of other alternatives, the presence of the random

[6] Amemiya provides an excellent survey of the econometric approaches used with qualitative response models.

component also permits the analyst to make probabilistic statements about consumers' behavior. Different probabilistic choice models can be derived depending on the specific assumptions made about the distribution of the random component. Random utility models are frequently used to rationalize stated choice or preference approaches to measuring attributes.[7]

"Stated choices" are decisions made in hypothetical markets in which there may exist no corresponding real choices. The approach involves surveys based on experimental design techniques that enable the statistical identification of the underlying preference functions. Random utility models can also be based on revealed preference (or market based) information and used to determine the value of attributes. Scanner data are now readily available, and they provide a plethora of information that might be applied to analyze branded products.

Anderson, De Palma, and Thisse developed a method to cast a demand system into a multidimensional characteristics framework with horizontally differentiated products. They used a discrete choice model to generate an aggregate demand system by summing (integrating) the probabilities that individuals would choose a variant of a differentiated product across characteristics space. Thereby explicitly linking discrete choices that are a function of characteristics into a continuous model, they were able to derive market level demands that could conceivably be incorporated into large institutional models. This approach has been used in a number of different settings. For instance, Nevo used scanner data to examine the ready-to-eat breakfast cereals market and found that brand level demand is a function of product-level characteristics and consumer preferences. He postulated that conditional indirect utility is a function of observed product characteristics and prices (price is just another attribute) and a random component for unobserved characteristics. Using a similar approach to Anderson, De Palma, and Thisse, Nevo was able to derive own- and cross-price elasticities. The elasticities were then used to compute price-cost margins that would prevail under different types of market behavior.

So attributes can be modeled conceptually, and a number of empirical studies have developed practical approaches to determine the value of attributes with discrete choice models and map this information into a demand system that could be used in a market model to conduct policy analysis. However, these approaches require substantial amounts of information on characteristics and are computationally intense. As a consequence, there is much work to do to institutionalize this framework in a large, multiproduct market model.

A Case Study of Food Safety Regulations

The discussion of market models, to this point, has been rather general. The purpose of this section is to illustrate these considerations in a case study of modeling food safety regulations.

From an economic perspective, there is an optimal level of risk of foodborne pathogens or other contaminates that is determined where the marginal costs and benefits of any regulation are equated. The challenge is to measure these costs and benefits. There have been a number of cost-benefit analyses of proposed and existing regulations (McDonald and Crutchfield; Roberts, Buzby, and Ollinger). However, the information developed in cost-benefit analysis is not always the same information that would be desired from a market model. Cost-benefit analysis does not answer questions such as the incidence of additional regulatory costs across consumers and producers. The following sections consider the demand side, supply side, and market equilibrium considerations important in modeling food safety regulations.

Demand Side Considerations

Food safety involves three crosscutting issues: information asymmetries, the risks associated

[7] Stated preference methods have advantages in that extended attribute ranges can be used, attributes are uncorrelated by design, and the method can be used to elicit preferences for alternatives that are not yet available (see Adamowicz, Louviere, and Swait).

with consumption, and the differentiated nature of products. If consumers are not fully informed about product characteristics, they may consume a dangerous product. Contamination of a food product with a pathogen, or other contaminate, is an **experience** attribute if the consumer becomes ill. However, with **credence** attributes (i.e., when the consumer cannot detect the quality even after consumption), the consumer does not experience the effect until a much later time.

The analysis of consumer risk aversion is complex (Choi and Jenson), and health risks, in turn, affect price and income elasticities. Studies have often indicated that consumers are willing to pay a large premium for zero risk when they already face low risks (Antle 2001). Consumer perceptions of risk are often inaccurate, in that they do not match scientific evidence of the true risk, and risk preferences are heterogeneous across consumers and across countries.

Applied analyses of food safety have typically used vertically differentiated product models (Caswell, Noelke, and Mojduszka). The problem with vertical differentiation is that quality is assumed to be objectively quantifiable and consumers are assumed to be homogenous. This approach may also have limited success in providing insights into the operation of markets for credence goods. Standards should increase consumer confidence and could increase demand.

Most of the demand side research on food safety is survey based and measures consumers' perceptions about the hazards of products and their willingness to pay for food safety.[8] Because of problems encountered with responses to hypothetical questions, contingent valuation techniques have been combined with experimental auction techniques (Fox et al.). Despite the advances in techniques, it is difficult to generalize the willingness to pay to reduce certain risks beyond the context of a given study.[9] As a consequence, the information provided by these methods may not be directly relevant to measuring the demand functions that are used in a market model. However, as suggested above, discrete choice models could be linked to continuous demand systems, if the important attributes are solicited in the survey or experiment. Also, there have been attempts to incorporate consumers concerns directly in conventional demand systems.[10]

Supply-Side Considerations

The issues of risk and information asymmetries are equally important on the supply side. Also, firms' decisions affect the quality of the product, and they may use quality to differentiate their products as a way to increase their market power. Cost estimates of pathogen reduction are typically accounting or engineering based. However, there have been attempts to estimate cost functions where cost is conditioned not just on output but also on safety and nonsafety attributes. For example, Antle (2000) showed that the cost function could be estimated by combining a hedonic model with a cost function. A firm can also take precautions to reduce the dangers associated with a particular activity. These costs of precaution could be represented by a cost function that includes the probabilistic cost of an accident. Kolsad, Ulen, and Johnson (1990) showed that the marginal cost of precaution would equal the marginal expected cost of the accident.

Maskus, Otsuki, and Wilson discussed the problems of accounting for the costs of regulation in terms of shifting the producer's supply function. However, there are many practical difficulties with price-based measures of the compliance costs of regulations. These regulations are not specified in some absolute monetary amount or as an absolute quantita-

[8] There are methods to use indirect evidence from the market place such as the individual's expenditures on related goods. An example of this technique is the cost of illness approach.

[9] Shin et al. extrapolated this value to the level of the U.S. population and found a willingness to pay that could be several times larger than the cost of illness estimates.

[10] Henneberry, Piewthongngam, and Qiang used an AIDS model to incorporate consumer concerns about food safety.

tive limit. Regulations are "complicated specifications of such characteristics as minimum quality, maximum toxicity, ambient characteristics in the production environment, and technical compatibility, along with rules of demonstrating conformity" (Maskus, Otsuki, and Wilson, p. 43). Regulations may raise fixed costs and have no effect on marginal costs. There are a number of uncertainties of how regulations are applied, especially in the international context. Regulations can truncate the distribution of risks faced by producers, affecting both the mean and the variance. Finally, the degree of market power determines how firms will respond to regulations, whereas the presence of product differentiation increases the probability that firms exercise market power.

Complete Model Considerations

A few theoretical models have analyzed the market equilibrium for food markets with safety considerations (Falconi and Roe; Holloway 1996). For the most part, these studies have accounted for relevant considerations—information asymmetries, market power, differentiated qualities, risk, multiple stage production, or marketing processes. However, from an applied perspective, there have been relatively few attempts to model food safety regulations with a complete model that brings the demand and supply sides together. These food market equilibrium models are much less complete. Examples of applied approaches have linked econometric models to epidemiological models and use an equilibrium displacement model to trace the cost of regulation. A selection of these studies is discussed below.

Mangen and Burrel tied a market model for hogs and piglets to a stochastic epidemiological model to simulate the effects of classic swine fever in the Netherlands. The epidemiological model gave the transmission of a disease through a population once an outbreak occurs. Although the model linked various stages in hog production, it did not address the upstream factor market, and downstream consumer effects are an amalgam of intermediate and final consumers. Trade effects in that study dealt with the broader European Union. Broader questions of market conduct, information asymmetries, or quality impacts were ignored.

Paarlberg and Lee used a nonspatial model to link the risk of foot-and-mouth disease in the domestic cattle market with beef imports from high-risk areas. The authors determined an optimal tariff for imports of beef from infected regions to protect domestic cattle and domestic producers. They did not include a stochastic specification, even though risk is involved. Only one level of the market was considered, and the emphasis was on trade policy, where the only policy is the link between the level of the tariff, the risk of exposure, and the magnitude of the loss. Questions of market-conduct, product quality or differentiation, information problems, and vertical market considerations were all ignored.

Unnevehr, Gomez, and Garcia used an equilibrium displacement model to determine the incidence of additional food safety regulations (costs) across various agents and to show the effect on producer welfare. The additional costs of Hazard Analysis and Critical Control Point (HACCP) were used to shift the supply functions for beef, pork, and poultry. Although these products are not substitutes in production, they are substitutes on the demand side. The shifts in supply cause changes in relative prices, and the model was used to trace the effects through the system and to determine who bears most of the costs of HACCP. However, the model only accounted for one level of the market. It did not account for imperfect competition, differentiated products, or trade.

The basic problem with market models that address food safety issues is that they are not comprehensive enough. Although a particular model may focus on a single aspect of food safety, they are not easily integrated into broader models. Nonetheless, in some cases, existing commodity models can be used to address the implications of a health regulation. For instance, the implications for prices of the closure of the U.S. border to imports of live Canadian cattle, because of a single reported case of bovine spongiform encephalopathy, could be adequately described with a multi-market commodity model.

Equilibrium displacement models may be a potentially fruitful approach, because they can accommodate a number of considerations including market power, quality considerations, vertical relationships, and risk. Other issues such as heterogeneity of producers and consumers, information problems, direct quantification of food safety rules, and microlevel analysis of unique situations, are best handled with idiosyncratic models. However, these models do not provide the breadth of cross-commodity linkages that the econometric multipurpose commodity models provide.

Conclusions

Both the nature of the agrifood sector and the policies affecting it are changing. Policymakers require information on a very broad range of issues, and no one model can hope to address all of these issues. We have assessed the information supplied by the large econometric partial equilibrium models currently maintained by a few research institutions. These models have a long history and are capable of addressing many relevant policy issues. To the extent that most U.S. farm programs are still directed to specific commodities (i.e., program crops), the coverage of these models is often adequate. Given the shift in the 2002 U.S. Farm Bill back to countercyclical payments, these models also provide useful information to help score budgets. The strength of these models is their cross-commodity coverage and the ability to explicitly link interdependent markets. However, these models are deficient in that they are not well designed to address vertical linkages in the food marketing chain and do not account for the growing importance of product attributes and intra-industry trade.

Can the existing institutional models be modified to address the six problem areas that we have identified? The answer is generally no, but there is some potential for improvement if the resources and data are available. The net trade nature of these models excludes the examination of intra-industry trade. Accounting for attributes and product differentiation is the most neglected aspect of policy models of any kind. Product differentiation could not be included in the institutional models without dramatic modifications that completely change the nature of the existing models.

Accounting for the vertical linkages throughout the supply chain is another weakness of the institutional models that are focused on a limited number of raw products and some first-level processing activities. Vertical relationships are typically dealt with through marketing margins. Developing a multilayered model, rather than a marketing margin model, begins with a more complete specification of food processing. With sufficient additional resources this may be possible, but data deficiencies begin to limit the policy questions that can be addressed. Accounting for vertical coordination mechanisms is an order of magnitude more difficult to model, and the appropriate data may not be available.

The related issue of market power is also unlikely to be addressed without a model that accounts for product differentiation. Accounting for vertical linkages, especially vertical coordination mechanisms, is also necessary for measuring market power. Data limitations are a big impediment to accounting for market power, and addressing this issue in a large institutional model does not seem practical.

The significant role of direct payments (decoupled payments) in agricultural policy is also difficult to model. Nonetheless, attempts have been made to adjust the large partial equilibrium models to account for the indirect impacts of direct payments (Adams et al.). Accounting for risk should be a priority in updating commodity models. Currently, factor markets are not addressed in the institutional models, but this omission could conceivably be rectified. This modification would account for the additional farm-level costs of programs, such as environmental and food safety programs.

Some of the problems of adequately addressing trade policy, such as modeling the appropriate mechanisms for Tariff Rate Quotas, although operationally difficult, have been addressed in at least one model.[11] Other broader issues, such as foreign direct investment, have not been addressed. However, addressing this issue requires adequate treatment of product differentiation and market power. Again, data are a major limitation.

Finally, it is probably not feasible to incorporate food safety considerations and some of the other policy issues discussed in this review into comprehensive institutional models. The existing attempts at modeling food safety concerns are very specialized to the circumstances they were designed to address. It is unlikely that these models can be generalized. The bottom line is that smaller idiosyncratic models may be better to address many of the issues of concern to policymakers, despite the fact that these models do not provide the broad commodity coverage that the big institutional models provide.

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