Applied General Equilibrium Analysis of Agricultural Policies*

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APPLIED GENERAL EQUILIBRIUM ANALYSIS OF AGRICULTURAL POLICIES

I. Why CGE Analysis of Agriculture?

The analysis of farm and food policies in the U.S., and many other developed market economies,[1] has long been dominated by agricultural economists who, by and large, have taken a partial equilibrium approach to these problems (Schuh).[2] Emphasis is placed on likely impacts of policies on net farm income, taxpayer costs, and (less frequently) consumer costs. Welfare conclusions are usually drawn by summing changes in consumer and producer surplus, along with taxpayer costs.[3] Analysts' attention tends to be focused on commodity prices and returns to the production of particular commodities. Links from factor payments to particular household groups, and ultimately to consumption, are rarely made. In contrast, CGE analysis makes these connections explicit, and thus offers a more complete accounting of (and hence a valuable perspective on) the incidence of farm and food policies.

In some cases, CGE analyses of agricultural policies can even reverse conventional wisdom. Thus an economywide analysis of the EC's Common Agricultural Policy (CAP) shows that, far from its stated objective of saving jobs, the CAP has probably contributed to increased unemployment (Stoeckel). CGE analysis of the effects of protection in Australia show that agriculture is <u>better</u> <u>off</u> after removal of its support -- provided similar measures are taken in the industrial sectors (e.g., Higgs). Support for the Australian manufacturing sector amounts to an implicit tax on agriculture. Many other such insights may be obtained by applying general equilibrium analysis to agriculture and related policies.

This survey will focus primarily on CGE analyses of Developed Market Economy (DME) agriculture. (The chapter by Sherman Robinson in this volume will survey CGE analyses of developing countries.) The demand for such analyses has been greatly stimulated by huge DME budgetary and consumer outlays for increasingly untenable agricultural policies. In 1986, direct and indirect transfers to agriculture by taxpayers and consumers amounted to 79% of the value of gross output of Japanese farmers. Similar measures for the U.S. and the EC-10 were 36% and 50%, respectively (USDA). The resulting tension in the agricultural marketplace has at times threatened to disrupt the entire international trading system. As a result there has been considerable interest in, and support for, the notion of bringing agriculture -- which has heretofore enjoyed exception from such rigors -- into the GATT. Many of the recent CGE analyses of DME agriculture have been developed with this type of trade/policy liberalization question in mind. While I will not focus directly on this issue, a number of the examples to which I will refer are drawn from this literature.

II. Limitations of the General Purpose Models

In a paper titled "Hidden Challenges in Recent Applied General Equilibrium Exercises," John Whalley emphasizes the need to move from general to special-purpose models if CGE analysis is to become more policy relevant. He notes that the CGE models of the 1960s and 1970s were developed partially in order to "demonstrate the feasibility of constructing applied general equilibrium models ... showing they could handle much larger dimensions than theoretical models" (p. 37). Application of such models to particular policy issues often involved redesigning the basic model, while carrying along considerable excess baggage. With model construction and computation now less of an issue, Whalley suggests that future efforts be directed at developing special purpose models, tailored to address specific issues. He notes that particular attention should be paid to parameter specification and the manner in which policies are modeled. This chapter may be viewed as a survey of recent attempts, in the context of farm and food issues, to meet some of these "hidden challenges".

There are a number of important features which have limited the impact which general purpose CGE models have had on agricultural policy issues. Most of the CGE models of DMEs treat agriculture (possibly along with forestry and fisheries) as a single, aggregate sector, producing one homogeneous product (e.g., Ballard, Fullerton, Shoven, and Whalley). This type of aggregation was essential in order to permit complete commodity coverage at a relatively uniform level of aggregation. However, when it comes to analyzing farm policies, more detail is required. This is because intervention varies widely across farm commodities, with some receiving a great deal of support (1985 U.S. sugar prices were five hundred percent of the world price), while others (such as the U.S. poultry industry) are virtually free of intervention. By lumping all of these products into one single aggregate, little can be said that would carry any weight with agricultural policy makers. The question of how disaggregate such models should be will be addressed in Section III of this paper.

A second critical limitation of the most common, general purpose CGE models of the previous decade is their tendency to devote too little attention to the specification of key behavioral parameters in the farm and food system. As a consequence, there is a wide gulf between the partial equilibrium models currently used in agricultural policy analysis, and the partial equilibrium behavior of their CGE counterparts. In some cases these discrepancies may be justified. However, in most instances the CGE models' parameters simply lack empirical justification. As a consequence, they can occasionally result in quite implausible sectoral behavior.

Generous federal and state funding, and close working relationships with other scientists and with industry have combined to result in an agricultural economic data base which is the envy of many applied economists. There is also more than half a century of applied econometric analysis of supply and demand behavior in agricultural markets upon which to draw. In short, agricultural economists know a lot about agriculture! To be effective, any CGE modeler who wishes to seriously tackle farm and food policy issues must be willing and able to capitalize on this wealth of data and behavioral information. In some cases this will require use of more general functional forms for representing preferences and technology in the CGE model. Section IV of this paper addresses the issue of parameter specification. The related question of length-of-run is discussed in Section V.

Another important feature of general purpose models which has limited their applicability to agricultural issues is their failure to distinguish land from other capital inputs. Yet the presence of farm land in the agricultural production function is critical. It is perhaps the most distinguishing feature of this sector of the economy. The presence of this essential, relatively immobile asset -- land -- assures a finite longrun supply response and hence a sharing of farm program benefits between consumers and the owners of this asset.

Land can also be an important instrument of public policy. For example, a significant aspect of intervention in U.S. agriculture involves the idling of productive acreage in order to raise commodity prices. Furthermore, farm land prices are themselves often a policy target. With relatively limited alternative uses (outside of agriculture), the price of land is determined predominantly by farm prices. Thus land prices are potentially quite volatile. Since land usually represents the major form of wealth holding for the farm population, the impact of public policy on farm prices and hence returns to landowners is of paramount importance to farmers and agricultural policymakers. There is simply no way around dealing with land markets if one wishes to appropriately model the agricultural sector. This is the subject of Section VI.

Section VII of this paper focuses on one of the specific hidden challenges identified by John Whalley -- namely the need for explicit modeling of public policies. There are many cases in which simple ad valorem equivalent representations, common among general purpose models, give rise to inaccurate, or even misleading conclusions. This is followed by a discussion of product differentiation and imperfect competition. The chapter closes with a discussion of directions for future research.

III. Data and Aggregation Issues How Detailed Should the Model Be?

Obviously there are limits to the amount of detail which can be provided by an economywide model. The general purpose models have logically opted for a relatively balanced treatment of the entire economy, given the constraints imposed by national accounting conventions. For example, the U.S. tax model outlined in Ballard, Fullerton, Shoven, and Whalley has nineteen sectors. Sectoral gross output, as a percentage of the U.S. total ranges from slightly less than one percent (mining) to a little more than ten percent (services). But most sectors fall in the 2-8% range (Ballard, et al., table 4.13).

A special purpose model focused on agricultural policy will necessarily be more lopsided in order to focus attention on particular issues. Perhaps the most extreme example of this is the world wheat model of Trela, Whalley, and Wigle. In their framework each country consumes two goods: wheat, and everything else. This permits them to focus on the global effects of wheat policies within a consistent CGE model. It also makes data and calibration particularly straightforward. Benchmark equilibrium wheat production and consumption data are readily obtained from (e.g.) the FAO and they may then obtain data on the other sector as a residual. Constant elasticity of substitution (CES) or transformation (CET) preferences and technology are calibrated to reproduce the supply and demand elasticities for wheat, as published by Valdes and Zietz, and they are "off and running" with a model! The recent work of Horridge and Pearce is quite similar in spirit. These authors specify a residual "other products" sector to round out the partial equilibrium trade model of Tyers and Anderson. McDonald adopts the same strategy in his four region CGE model which focuses on the U.S., the European Community, and Japan.

Given the difficulty of constructing a benchmark equilibrium data base for a CGE trade model, there are obvious advantages in a model specification which has a large "residual" sector. However, there are important drawbacks associated with this backdoor approach to arriving at a complete CGE model. In practice, the dividing line between the agricultural and nonagricultural economy is not all that clear. Furthermore, in the case of some agricultural policies, the "grey area" between these two groups of sectors is where the most interesting "action" is.

Consider, for example, the U.S. sugar program. Support for U.S. sugar producers is achieved indirectly by administering an import quota on partially refined sugar, which is tightened until the domestic price of sugar reaches a prespecified target. The greatest source of pressure on the U.S. sugar quota has come not from the farm sector's supply response, but rather from the manufacturers of substitute sweeteners -- in particular high fructose corn sweeteners. This industry is dominated by a handful of firms who have become a very effective lobby for the sugar program. They have also made a concerted attempt to mobilize corn producers in support of this import quota on sugar, arguing that the derived demand for corn generated by production of this sweetener substitute lends considerable support to the market price of corn. While it has already been partially processed, traded sugar must be further refined for use in the domestic market. As a consequence, successive tightening of the quota has seriously hurt domestic sugar refiners. In summary, some of the major actors in the U.S. sugar program are not farm sectors at all, rather they are food manufacturers.

Rendleman has recently assessed the economywide impact of the U.S. sugar program. He utilizes a 17 sector CGE model, tailored to capture the complex market relationships among sugar producers, other agricultural interests, food manufacturers, and by-product markets. He finds that short-run losses to sugar producers and the manufacturers of substitute sweeteners are, to a great extent, offset by gains to the ailing sugar refiners when the quota is eliminated. He also concludes that corn producer support for the U.S. sugar program is likely misplaced, since the presence of the quota appears to offer very little support to domestic corn prices. The message here is that analysis of particular commodity programs often requires disaggregation of nonfarm food manufacturing activity as well.

Applied GE models attempting to address the overall impact of farm and food programs need to disaggregate sufficiently to isolate distinct types of commodity market intervention. Hertel, Thompson, and Tsigas distinguish nine different farm products and about a dozen processing sectors in their attempt to assess the impact of unilateral agricultural policy liberalization in the United States. In their work on U.S. agricultural policies, Robinson et al. began with a model in which 3 farm sectors were broken out (Robinson, Kilkenny, and Adelman). They have subsequently found it desirable to disaggregate to 8 agricultural and 8 food processing sectors (e.g., Hanson, Robinson and Tokarick) in order to capture the major differences among various farm and food policies.

The question of disaggregation becomes more difficult in those cases where the general equilibrium modeler wishes to deal explicitly with agricultural trade, and related domestic policies, among a variety of countries. There are severe data constraints which usually result in less input-output detail in such models. For example, the first decade of work on the IIASA model was limited to nine commodities, of which eight are agricultural products and one is a residual, "nonagriculture" commodity (Fisher, et al). More recently, the OECD has developed a trade-CGE model (Burniaux, et al.), which has 13 industries, of which 6 pertain to farm and food products. Unfortunately, at the farm level there are only two sectors (livestock and other agriculture) which makes it difficult to capture the effects of specific commodity programs such as those for rice, sugar, wheat, etc. The impact of these diverse programs ends up being averaged over a broad composite of goods. In short, the move from one-country to multiple country CGE models entails some hard choices.

To illustrate the difficulty of analyzing agricultural trade liberalization using a model which aggregates all crop products, consider the following partial equilibrium evidence regarding the likely price effects of such an exercise. [Estimates are based on USDA's SWOPSIM model of agricultural trade in 1986 (Roningen and Dixit).] When the U.S. alone liberalizes agricultural policies world price effects range from -2.6% for oilseeds to +22.8% for sugar. The aggregate world price effect on agricultural products (crops and livestock) is +5.9%. When all industrial market economies liberalize their agricultural policies, price increases for crops range from +6.4% to +52.7%, with an aggregate agricultural price rise of 22% for products covered by this model. In light of the fact that agricultural interest groups are generally aligned with specific commodities, failure to deal with this type of diversity can be somewhat limiting when it comes to specifics in any debate over farm policies.

The flip side of this issue is that the magnitude of these world price changes also indicates that many single country analyses, however detailed, may be misleading. Of course, modelers can make some sort of ad hoc adjustments in order to account for policy shocks which have important world price effects.[4] But these one country models remain trapped in what is essentially a unilateral environment, devoid of the type of policy interactions which characterize international trade in agriculture. Consider, for example, the fact that almost half of the $26 billion which the U.S. transferred to the farm sector in 1986 was required simply to offset the effects of other industrial market economy's agricultural policies (Blandford, deGorter, Dixit, and Magiera). This interdependence between DME protection of agriculture is explored in some detail in Harrison, Rutstrom, and Wigle, who use a multilateral CGE framework to simulate the effects of an agricultural trade war.

Agriculture as a Multiproduct Industry

The generic, general purpose CGE model is typically characterized by single product, constant returns to scale industries. However, agriculture departs significantly from this mould. Econometric tests for nonjointness in aggregate agricultural production are consistently rejected (e.g., Ball). There are numerous explanations for this apparent jointness in production including technological interdependence, the presence of lumpy/shared inputs, and the presence of a significant allocatable fixed input in the form of land (Shumway, Pope, and Nash).

The problem posed by the presence of multiproduct sectors in a CGE model is that the addition of potential output-output, and input-output interactions vastly increases the number of parameters to be specified. One common solution is to impose input-output separability (e.g., Dixon, et al.). The implication of this particular restriction is that the optimal output mix is invariant to changes in relative input prices. This is a strong assumption which violates one's intuition (e.g., the optimal mix of corn and soybeans is sensitive to the price of fertilizer). It also is persistently rejected by the data (e.g., Ball).

Another problem confronting the modeler seeking to treat agriculture as a multiple product sector is the presence of commodity-specific factor market interventions. For example, in order to qualify for corn output subsidies in the U.S., it is necessary to idle a certain percentage of one's established corn acreage. This in turn has a differential effect on the shadow price of land in corn vs. (e.g.) soybean production. Lee and Helmberger demonstrate how this can result in own-price effects which are "too small" relative to cross-price effects. This, in turn, can introduce nonconvexities into a standard multiproduct profit function for U.S. agriculture.[5]

If one is willing to argue that jointness in agricultural production is solely due to the presence of an allocatable fixed input, then it is possible to revert to modeling commodity production as a set of single product activities -- bound together by the presence of a fixed amount of land. Indeed, attempts have been made to estimate agricultural technology under these assumptions (Just, Zilberman, and Hochman). It is also a common specification in agriculturally focussed CGE models, and has the advantage of facilitating commodity-specific interventions in the land market (Hertel and Tsigas, 1991).

What About Farm Size?

Another complexity in modeling the farm sector has to do with the treatment of farm size. In the U.S. a relatively small group of commercial farms produces the majority of agricultural output. There are a great number of small farms, many of which are part-time operations. For example, in 1987, 52% of the farms had sales of less than $10,000 and consequently accounted for only 6% of gross farm income (Sumner). The inexorable downward slide of average costs leaves small producers with below average, sometimes negative, returns to their equity and own-labor. This process is driven by persistent technological change, and at any particular moment, the agriculture sector is in a state of disequilibrium with regard to the composition and size of farms. For example, in their econometric analysis of the period from 1947-74, Brown and Christensen show that, while family labor in agriculture dropped by two-thirds, the estimated optimal level of this input also dropped dramatically. As a result, the ratio of observed to optimal family labor hardly changed.

While the issue of farm size is an important one, it is essential that CGE modelers with an interest in agriculture focus on aspects of the farm sector which: (a) are central to the questions they seek to answer, and (b) to which they can contribute some added insight. I would argue that neither of these applies (in most instances) to the farm size issue in developed market economies. Most production comes from a relatively small group of commercial farms. Those are the operations which dominate the data used to estimate price elasticities, and their behavior is more nearly consistent with the neoclassical paradigm prevalent in CGE analysis. Thus, in most cases, we should focus on modeling representative commercial farm operations. Modeling the evolution of the distribution of farms by size is an important issue, but not one at which CGE models have any comparative advantage.[6]

Of course there are exceptional cases in which farm size becomes relevant for CGE analysis of agricultural policies. A good example is provided by the Canadian dairy program, whereby individual farms are assigned a production quota. Econometric evidence indicates that this has contributed to the presence of unexploited scale economies (Moschini). Thus it is important to build this inefficiency into the initial equilibrium. Robidoux, Smart, Lester, and Bearsejour have done this (both for dairy and poultry) in their analysis of Canadian farm policies. They find that agricultural policy liberalization generates considerable "rationalization" in the dairy industry.

The Concept of a Representative Year Benchmark

Agricultural production, prices, and returns to assets are notably volatile. The vagaries of weather, long gestation periods, price-inelastic demands, and heavy (but unpredictable) intervention by governments all contribute to this volatility.[7] It is not uncommon to find enormous swings in the components of agricultural value-added reported in the national accounts.[8] This cost share volatility can translate directly into volatile model results, as has been demonstrated for Australia by Adams and Higgs, using the ORANI model. Since the share of fixed capital and land in the primary factor aggregate is a key parameter in the calibration of ORANI's agricultural supply response, variation in this share translates directly into variation in the supply elasticity. The authors show that such variation can even alter the predicted macroeconomic consequences of farm sector shocks. This led the authors to the development of a "representative year" data base for Australian agriculture. (They also incorporate underlying trends into this synthetic data set, which gives it a forward-looking flavor.) In a somewhat more ambitious undertaking, Harrison, Rutherford, and Wooten (1989a) construct a sequence of SAMs for the European Community with which they proceed to analyze the same experiment (removal of the Common Agricultural Policy) over a period of 12 years. A logical extension of this effort would be to use this time series data to estimate a representative benchmark equilibrium for the entire economy. Such developments strike me as being essential to future efforts at CGE modeling of agriculture. They also deserve some attention by nonagricultural CGE modelers.

IV. Parameter Specification

As was pointed out above in Section II, there is a long history of applied econometric work in agricultural economics. While general agreement does not exist on the specific value of most individual parameters, there is considerable interest among agricultural economists in the assumed value for individual elasticities used in policy modeling. If these cannot be defended, the credibility of the entire analysis may be at stake. Thus it is especially productive to give careful consideration to parameter specification in CGE models which have a farm and food policy orientation.

Limitations of the General Purpose Models

Consumer Demand: There is a considerable body of work available which reports the results of disaggregated, complete demand systems for food and nonfood commodities (e.g., Huang; Huang and Haidacher). There is a strong tendency for food products to be price- and income-inelastic. However, individual elasticity values vary widely among food groups, with consumer demands for grains being quite unresponsive to price, while livestock products are more responsive. It is impossible to capture this diversity of price-responses with an explicitly additive demand system such as the Linear Expenditure System (LES). Those studies which simplify even further, by assuming Cobb Douglas preferences (e.g., Robidoux, et al.; Robinson, Kilkenny, and Adelman; Kilkenny and Robinson) risk overstating some uncompensated price elasticities by a full order of magnitude. This is particularly problematic when agricultural price policies are being examined, since consumer demand elasticities are critical in determining the incidence of changes in these policies. By overstating consumers ability to respond to a price increase, such models will overstate the backward shifting of the effects of such a shock.

Producer Technology: The predominance in CGE models of Leontief (fixed coefficient) technology with CES substitution in value-added has its origins in the associated computational advantages. By assuming fixed intermediate input coefficients, the entire equilibrium problem can be reduced to one of finding a fixed point in factor price space (Ballard, et al.). This vastly reduces the computational cost of CGE analysis, which was an important consideration prior to the development of more efficient algorithms and more powerful computers.

However, intermediate input substitution plays an important role in the farm and food system. In particular, the potential incidence of farm programs is closely circumscribed by the ability of livestock producers and food processors to substitute among raw agricultural products. For example, the gains from a corn price support program are shared with soybean producers because the corn-soymeal mix in livestock feeds is altered in response to changing relative prices. Similarly, as noted above, high fructose corn syrup has been widely substituted for sugar in the U.S. food and beverage sectors, as a consequence of the sugar import quota.

Substitution among intermediate inputs and between intermediate and primary inputs also plays an important role at the farm level. Empirical evidence from U.S. agriculture (e.g., Hertel, Ball, Huang, and Tsigas) indicates greater potential for such substitution, than for substitution within the primary factor aggregate (land, labor, and capital). Because many important farm policies represent interventions in the primary factor markets (e.g., acreage reduction programs and subsidized investment), proper assessment of their impact on target variables such as employment and land rents hinges crucially on the specification of farm technology.

Trade Elasticities: Since cross-price effects play an important role in the U.S. farm and food economy, it is no surprise that they also show up in the rest of the world's response to U.S. price movements. Unfortunately such cross-price export demand elasticities are notably difficult to estimate (Gardiner and Dixit). Thus one is forced to rely on simulation results from a global agricultural trade model to measure them (e.g., Seeley). As is demonstrated in the appendix, these cross-price price effects are empirically quite important.

For example, while Seeley estimates a four-year own-price elasticity of export demand for U.S. wheat of -2.15, he finds that the total elasticity (when all grain and oilseed prices move together) is only -0.54. Since most farm sector interventions affect these commodities simultaneously, cross-price elasticities of export demand can be expected to play an important role in any policy simulation. Yet most one-country, general purpose CGE models abstract from cross-price effects in export demand (e.g., Ballard, et al.; Robidoux, et al.; Burniaux, et al.; Robinson, Kilkenny, and Adelman).

Implications for Policy Analysis: There will always be limitations in the way one is able to represent the basic structure of an economy in a CGE model, and so the critical question becomes: Are these limitations sufficient to warrant the extra effort involved in remedying them? In order to investigate this issue I have chosen to focus on one of the most inefficient farm policy tools -- namely the idling of productive acreage in order to boost farm prices. Results are based on a special purpose CGE model outlined in Hertel, Ball, Huang, and Tsigas, which utilizes a flexible representation of consumer preferences and producer technology. I then ask the question: What is the cost of successively restricting preferences and technology along the lines suggested by some of the general purpose models?

The results from these experiments are summarized in table A1 of the appendix. They indicate that a generic, general purpose CGE model which oversimplifies consumer preferences and producer technology, and which omits cross-price effects in export demand, will overstate the welfare costs of acreage controls. In the specific illustration provided in that table, the welfare cost of incremental acreage controls designed to raise program crop prices by 10% is overstated by 60% ($4.2 billion vs. $2.6 billion in the unrestricted model). This follows from two basic flaws in the general purpose models. First of all, they tend to overstate the farm level demand elasticity for these crops. Secondly, they tend to overstate the ability of farmers to substitute away from the land input. However, it should be noted that the direction of bias is not unambiguous. For example, when taken alone, the assumption of no substitutability in intermediate uses leads to an understatement of these welfare costs.

At this point the question arises: If improved parameter specifications are desirable, what practical alternatives are available? This leads into a discussion of alternative functional forms for the representation of preferences and technology.

The Problem of Functional Form

The model used to generate the results discussed in the preceding section is a linearized representation of a CGE model. Thus key parameters are expressed directly as elasticities. This facilitates incorporation of the estimated consumer demand system, which is only integrable at the benchmark equilibrium budget shares.[9] However, since no underlying functional form is specified, it is impossible to update these elasticities as relative prices change. Consequently, linearization errors cannot be eliminated. In order to rectify this problem, globally well-behaved functional forms for utility and production relationships must be specified (Hertel, Horridge, and Pearson). Much work has been done in this area in recent years (e.g., Diewert and Wales; see also the chapter on functional forms authored by Rutherford and Perroni elsewhere in this volume). However, most of this work is couched in terms of "fully flexible" functional forms, i.e., those containing an unrestricted matrix of partial elasticities of substitution. To go from a CES/LES specification to a so-called "flexible functional form" is to go from one to N(N-1)/2 substitution parameters (where N is the number of choice variables). While there may be cases where this large amount of information is available, it is probably a bigger step than many CGE modelers would like to take. In short, the use of fully flexible functional forms in CGE analysis may be excessively ambitious for many applications.

Is there any intermediate ground? In a somewhat overlooked 1975 article, Hanoch proposed a class of implicitly additive functional forms which are associated with N independent substitution parameters. He made precisely the argument alluded to above -- namely that there may be cases where a generalization of the CES which falls short of being "fully flexible" might be useful. Furthermore, under implicit additivity, N is precisely the number of free parameters required to match up with a vector of N own-price elasticities of supply (demand). The implicit additivity restriction was first employed empirically in order to represent production possibilities in Australian agriculture, within the context of the ORANI model (Vincent, Dixon, and Powell). These authors used the CRETH (Constant Ratio Elasticity of Transformation Homothetic) system, which is a primal specification. The Constant Difference Elasticity (CDE) functional form is a dual specification which is slightly more general, and somewhat easier to manipulate. It has been employed to estimate demand relationships in agriculture (Surry; Hjort). Recently, it has been used in CGE analysis (Hertel, Peterson, Surry, Preckel, and Tsigas).

V. Short, Medium, or Longrun?

The Role of Commodity Stocks

The timeframe chosen for a CGE simulation has important implications for a variety of features which are critical to the outcome of the experiment. In the very short run, crop production does not adjust and, in the absence of stocks, supply shocks cause wide swings in commodity prices. As a result, there are substantial incentives for stockholding -- either private or public -- in the case of nonperishable crop commodities. In the longer run, the importance of stocks is diminished, since continued stock accumulation or decumulation quickly becomes infeasible in the context of a global farm economy.

Since most CGE analyses focus on the medium run (which I take to be 3-5 years), it is common to abstract from commodity stockpiling -- assuming that the associated price effects will only be transitory. However, any annual agricultural data set will include this type of "inventory demand" (or supply). One solution is to do is to purge such demands from the benchmark equilibrium data set, in the process of constructing a representative year data set (Adams and Higgs).

Nevertheless, in any given year, stockpiling of commodities may represent a substantial budgetary cost which is of considerable interest to policymakers. Thus some CGE modelers have attempted to incorporate them into their analysis. Harrison, Rutherford, and Wooten (1989a; 1989b) develop a model of the European Community's Common Agricultural Policy in which excess market supplies are purchased, and either stored or unloaded onto world markets (with the help of an export subsidy). Stored commodities "are 'eaten' by EC government agents" (presumably they are stored until they spoil). Thus, they do not return to the marketplace, and hence do not generate future utility for private agents in this model.

In general some stocks are unloaded in the future. Indeed in some cases the U.S. Commodity Credit Corporation has made a handsome profit on such resales (e.g., sugar in the late seventies). Thus, there <u>are</u> benefits associated with holding commodities in storage. This is reinforced by the fact that when U.S. wheat and corn stocks get too low, policymakers tend to get nervous. As a result, they are likely to reduce acreage set-aside requirements (as was done following the 1988 drought) and attempt to temporarily stimulate production in fear of being caught short in the future. One possible approach to capturing these benefits in a static, deterministic model is to specify a stockholding utility function. Of course utility is derived not from the stocks themselves, but rather from the ability to stabilize prices within a prespecified price band. The amount of stocks required to do this is a function not only of variability in production, but also the pricing policies and political decisions of major importing countries. Thus the parameters of such a stockholding utility function will not be invariant to changes in the international trading environment.

Factor Mobility

As the time horizon for a CGE model lengthens, there is increased potential for production to adjust in response to a policy shock. In the limit, if all factors were perfectly mobile and the farm sector were relatively small, supply response would be perfectly elastic. However, all farm factors of production are probably never perfectly mobile. Farm land, in particular, often has few alternative uses and thus experiences more of a price adjustment than other factors in the long run. (I will discuss the sector-specificity of farm land in greater detail in Section VI.) Also, family labor, farm structures, and some types of capital are relatively immobile in the short- to medium-run.[10]

To highlight the importance of factor mobility assumptions in determining the incidence of farm programs, consider the following evidence taken from Hertel, Thompson, and Tsigas. They analyze the impact of unilateral elimination of U.S. agricultural support policies in both the shortrun and the longrun. The shortrun is characterized as the period over which both U.S. and foreign farm labor and capital are unable to adjust to this major shock. Thus shortrun export demand elasticities are used, and U.S. farm labor, crop and livestock capital are all assumed immobile out of agriculture. The estimated shortrun loss to these factors (in 1987 dollars) is $12.8 billion. The distribution of these losses is determined by the estimated elasticities of substitution in the farm sector. In this case the losses are distributed as follows: labor 37.3%, land 36.5%, livestock capital 18.2%, and crop capital 8.0%. In the long run, the effect of mobile labor and capital on the elasticity of farm supply dominates the impact on farm level demand of larger export demand elasticities. As a result, the total producer burden falls to $5.7 billion. However, now all of this is borne by the sector-specific factor -- land. Thus the pattern of factor incidence can vary considerably, depending on assumptions about factor mobility. In this case it is labor, not land, which bears the largest burden in the short run.

Exactly how "long" is the long run in models assuming perfect factor mobility? This depends in part on the size of the shock. In the above experiments, the adjustments to attain a new equilibrium include a 5.5% reduction in the agricultural labor force, and a 14% decline in the stock of farm capital. Are these adjustments large? Not when compared to other forces at work in the farm sector. For example, Hertel and Tsigas (1988b) estimate that the average <u>annual</u> decline in the derived demand for farm labor as a consequence of technological change during the post WWII period was 4.3%. The needed capital stock adjustment is also not too large when compared to average annual rates of economic depreciation for farm machinery, which range from 9.7% to 25.4% depending on the equipment in question (Hulten and Wykoff).

Of course, these relatively modest adjustments likely mask more dramatic regional and farm-specific effects. Also, if yours is the farm that goes under as a result of the new policies, the adjustment is hardly marginal!

Nevertheless, in view of the fact that: (a) rigidity is greatest for downward price movements, and (b) this policy experiment is the most dramatic one that could be inflicted on U.S. agriculture (policies are completely and unilaterally eliminated), it seems reasonable to expect that the period of adjustment is not more than the 3-5 year time horizon usually assumed.

Supply Elasticities -- Large or Small?

Closely related to the issue of factor mobility and incidence of farm subsidies is the question of supply elasticities for agricultural commodities. Despite decades of econometric work in agricultural economics, there remains considerable room for debate about the size of agricultural supply elasticities. Studies based on single equation models fitted to time series data have generally yielded aggregate agricultural supply elasticities in the range of 0.1 to 0.4 (Peterson, 1988). These results have long flavored the debate over farm policy, since they make output subsidies look a lot like lump sum transfers! One problem with such studies is that multicolinearity often precludes inclusion of a complete set of disaggregate prices (or quantities). Partly as a result of this, it is often unclear what is being assumed about particular decision variables facing the farm firm. Are they fixed or variable? Obviously if they are fixed, we expect smaller supply elasticities.[11]

An alternative approach to the estimation of supply response from time series data involves specification of a restricted profit function which, in turn, gives rise to a complete system of supply and demand equations in which decision variables are either fixed (quantity enters the supply equation) or variable (price enters the equation). Use of symmetry, homogeneity, and curvature restrictions help to overcome the problem of collinearity in such a system. A recent example of this approach is provided by Ball, who estimates a 5 output, 6 input system for U.S. agriculture, derived from a translog profit function which is constrained to be convex in prices at the point of approximation. It is restricted only on an exogenously determined quantity of own-labor (i.e., self-employed farmers). He obtains individual commodity supply elasticities ranging from 0.43 to 1.11. Furthermore, his outputs all exhibit gross complementarity.[12] Thus the aggregate supply response is much larger. Revenue share-weighted row sums of the output price submatrix sum to an aggregate supply elasticity of 3.6.

There are two problems with econometric estimates of supply response based on time series data, both of which result in understating the longrun elasticity. First of all, as pointed out by Peterson (1979), many commodity price movements are transitory. Thus the degree of expected long run price variability is easily overstated in such a data set (unless some sort of "expected price" is used). As a consequence, the estimated supply elasticities, based on observed quantities, are understated.

The second problem in most models based on time series data has to do with the treatment of technological change. This is generally handled with some sort of time trend proxy. Yet we know that the long run pattern of technical change is, at least in part, a function of relative prices (Hayami and Ruttan). Griliches (1960) argues that these time trends pick up some of the supply response which should in fact be attributed to the long run price elasticity of supply.

Peterson (1988) attempts to overcome these problems by using cross-sectional data from 119 countries to estimate long run agricultural supply response. His procedure is complicated by the need to first estimate input price indices, which are conditional on the assumption of Cobb-Douglas production function. His single equation estimate of the aggregate supply elasticity is 1.19, which is considerably larger than comparable single equation estimates based on time series data.

Supply response in a CGE model is typically a function of two things: (a) the assumed production technology, and (b) the specified degree of factor mobility. For example, with a CES agricultural technology, and a combination of perfectly elastic and perfectly inelastic factor supplies, the supply elasticity is given by:

$$\eta_s = (c_V/c_F)\ \sigma$$

Here σ denotes the (constant) elasticity of substitution, c_V is the cost share of variable inputs and c_F is the cost share of fixed inputs. Model calibration for such a case may proceed by one of two routes. The first is to take some estimate, $\hat{\eta}_s$, such as that from Peterson's study, and combine this with the benchmark equilibrium values for c_V and c_F to obtain θ. The problem with this approach is that, if you really believe that the technology is CES, then η_s varies as a function of relative prices (and hence varying shares -- provided $\sigma \neq 1$). The supply elasticity is not a constant parameter in such a model. In the developed market economies, where purchased inputs are cheap relative to the opportunity cost of family labor, we observe a large value of c_V, relative to c_F.[13] For any given value of σ, this gives rise to a larger value of η_S. Thus Peterson's cross-section estimation of η_s will understate supply response in the case of a country such as the United States, where c_V/c_F is large, relative to the sample mean.[14]

In summary, a brief overview of the evidence on agricultural supply response yields, at one extreme, very small supply elasticities based on single equation methods and time series data. Multiple equation, applied duality methods result in much larger supply elasticities. Also, single equation models fitted to cross-section data give substantially larger supply response. For the reasons I have given, I believe the larger elasticities are closer to the truth. If this is correct, then agricultural pricing policies are much more distorting than is indicated by many agricultural models.

VI. The Treatment of Agricultural Land in CGE Models

Given its unique role in agricultural production, the treatment of farm land in CGE models deserves special attention. Here there are two key issues which I will address. The first pertains to the sector-specificity of land. I.e., are there significant alternative nonfarm uses for this input which might contribute to determining its price in the long run? The second issue has to do with the heterogeneity of farm land and subsequent limitations on its mobility among uses within the agricultural sector.

Sector-Specificity of Farm Land

Unlike labor and capital, land is geographically immobile. As a result, it is common to assume that it is a sector-specific asset which ultimately bears all of the producer burden of a reduction in farm support. For example, Hertel, Thompson, and Tsigas estimate an 18% reduction in land rents following unilateral elimination of U.S. farm programs. Vincent (1989b) estimates that Japanese farm land rents would fall by 68% following unilateral liberalization in that country's agricultural sector. Is there a chance that such price reductions might stimulate nonagricultural uses of farm land? If so, this type of quantity adjustment would serve to dampen the landowner losses (see, for example, the work of McDonald).

The answer to this question will clearly vary by region and by country. In the U.S., nonagricultural uses have been shown to play a role in determining the value of farmland in selected metropolitan areas (e.g., Lopez, Adelajo, and Andrews), but this has not proven to be an important determinant of aggregate agricultural land values. Furthermore, most of the commodities grown near urban areas are not the traditional program commodities which are most dramatically affected by U.S. farm policy. Thus the potential for nonfarm uses of agricultural land dampening the downward adjustment of rental rates following unilateral agricultural liberalization would seem quite limited in the U.S.

In the case of Japan, where (a) the capitalized value of farm program benefits represents a larger share of land's claim on agricultural output, and (b) the proximity of farm land to major population centers is much greater, I would expect the demand for residential, recreational, and commercial land to place a significant floor under farm land values. Of course, the degree to which such adjustment can occur depends on accommodating changes in land use legislation. In Japan, "landowners must obtain the permission of the prefecture or of the Ministry of Agriculture, Forestry, and Fisheries in order to transfer farmland into other uses" (ABARE, p. 75). Extremely favorable property and inheritance taxation of farmland, coupled with high rates of capital gains taxation serve to further discourage movement of land into nonfarm uses. As a result, the percentage of land devoted to agricultural uses in the three major metropolitan areas in Japan (16%) exceeds the share of this land devoted to residential, commercial, and industrial plant uses (11.5%). It also exceeds the share of farmland in Japan's total land area (15%) (ABARE, p. 316).[15] Despite these distortions in the land market, there is some recent evidence of the potential for nonfarm uses to support agricultural land values. Between 1979 and 1985 the relative price of rice to rice paddy land fell by about 20% (ABARE, p. 321). This may well be due to speculative demand fed by the rapid increase in nonagricultural land values.

Heterogeneity of Agricultural Land

Abstracting from the question of how much land might move between farm and nonfarm uses, there are important modeling issues deriving from the heterogeneity of such land in agricultural production. The capacity of a given acre of land to produce a particular farm product varies with soil type, location in the watershed, and climatic conditions. These characteristics all combine to determine the yield, given a certain level of nonland inputs. To treat all farmland as homogeneous is to assert that one can grow oranges in Minnesota at the same cost as Florida (i.e. without greenhouses)! Models based on this structure will overstate supply response, since they don't take into account the agronomic and climatic constraints placed on the production of specific farm commodities. The trick for a CGE model is to capture the essence of such constraints without being forced to develop a full-blown model of agricultural production by locality and land type.

Perhaps the simplest method of constraining acreage response in a CGE model is that employed by Hertel and Tsigas (1988a) (see also, McDonald). They specify a transformation function which takes aggregate farm land as an input and distributes it among various uses in response to relative rental rates. Given a finite elasticity of transformation, rental rates will differ across uses.

The next level of complexity in modeling the heterogeneous nature of agricultural land involves drawing a distinction between land types and land uses. In this framework, equilibrium in the land market involves equal (after-tax) rates of return on any given type of land. However these land types substitute imperfectly in the production of a given crop, and so there exist differential rental rates across land types. Robidoux, Smart, Lester, and Beausejour adopt this type of specification in their CGE model of Canada. They specify CES aggregator functions that combine three land types, each of which is used -- to some degree -- in the production of six different farm products. An interesting wrinkle in their approach is the way in which they estimate benchmark equilibrium rental rates, by land type. These are obtained by regressing total land rents in each sector on the observed quantity of each land type used in that sector. In equilibrium, the land-specific rental rate (i.e., the coefficient on acreage) must be equal across uses.

The Robidoux, et al. approach deals with differences in land type, but not regional or climatic differences. Introducing these further dimensions brings us to the ultimate level of complexity -- as evidenced in some of the programming models of agricultural production. This kind of detail may well carry most CGE analyses into the region of diminishing returns.

VII. Modeling Policies That Affect Agriculture

As noted in the introduction, one of the important areas for future work identified in Whalley's "Hidden Challenges" paper involves improved modeling of public policies. This is nowhere more important than in agriculture, where, for some commodities in certain countries, the value of policy transfers sometimes exceeds the gross domestic value of production (USDA, 1988). Such interventions are not only large, they are also diverse. For example, it is not uncommon for agricultural policies to send conflicting signals regarding resource allocation. Input subsidies frequently coexist with supply control measures. Furthermore, many agricultural policies are not easily amenable to "ad valorem equivalent" modeling (Kilkenny, 1991; Kilkenny and Robinson, 1988; McDonald; Whalley and Wigle).

Modeling Voluntary Participation

One of the more vexing problems in agricultural policy modeling has involved the search for an appropriate framework with which to model voluntary farm programs. Voluntary participation has been a hallmark of the U.S. grains programs which have required farmers to idle a certain proportion of their base acreage in order to qualify for a variety of program benefits including payments on output. The fact that participation rates vary from year to year, indicates that producers are an economically heterogeneous group. The most common approach to modeling these programs has been to derive an average "incentive price" which, when combined with the supply shift due to idled acreage, would have induced the observed market supply of the crop in question (Gardner, 1989). However, such efforts generally ignore the impact that changing program parameters can have on important components of the problem such as variable costs per acre, optimal yields, and the nature of the supply shift. In reality, this is a complex, highly nonlinear problem.

Recently, Whalley and Wigle have proposed a new approach to modeling participation in the U.S. grains programs. They specify an explicit distribution of farms that reflects differences in their underlying cost structure such that the incentive to participate varies across five broad classes of farms. As program parameters or market conditions change, the participation rate varies endogenously. For example, introduction of a more attractive program will induce additional farmers to set aside the required acreage in order to qualify for program benefits. Tsigas, et al. have extended this framework to incorporate a continuous distribution of land, so that land capacity rather than technology becomes the motivating factor for differential participation. They subsequently calibrate this distribution using data from multiple years. All of this work highlights the differential incidence of farm programs on participants, nonparticipants, and those who are roughly indifferent to participation.[16]

Interventions in the Processed Product Markets

In many cases support for farm commodities is provided indirectly, by purchase of (or protection for) processed products. For example, the primary mechanism for supporting U.S. fluid milk prices involves purchases of cheese, butter, and skim milk powder by the Commodity Credit Corporation (CCC). Similarly, U.S. sugar prices are supported by a quota on partially processed sugar. This type of indirect approach to supporting the farm sector can have important implications for policy analysis, and hence for the appropriate structure of a CGE model.

In the case of the dairy program, CCC purchases have generated considerably more processing capacity in the industry than would otherwise be required. Any lowering of support prices translates into lower CCC purchases and redundant capacity. As a consequence, dairy processors have moved into the forefront of the dairy lobby. Similarly, as noted above, the U.S. sugar quota has generated a unique set of processor advocates as well as opponents. These effects, in addition to the change in returns to dairy and sugar farms must be captured by any model choosing to focus on such policies.

Funding of Agricultural Policies

The mechanism for funding farm policies can also have important implications for CGE analysis. Harrison, Rutherford, and Wooten (1989a; 1989c) explicitly link expenditures on the EC's Common Agricultural Policy to the level of the value-added tax (VAT) used to finance activities of the European Common Market. Thus, in their model, increases in agricultural support levels translate into increases in the VAT rate -- just as we have observed over the past decade.

In other cases the commitment to an agricultural program is not unbounded. For example, until recently the main mechanism for supporting agriculture in Brazil was through cheap credit. Since these funds were offered at persistently negative real interest rates, demand was essentially unlimited and the credit was rationed. As a result, these expenditures had relatively little effect on production levels in agriculture -- in effect becoming inframarginal transfers (Brandao).

The Role of Economywide Policies

Federal, state, and local tax codes also tend to affect agriculture differentially. In fact, Hertel and Tsigas (1988a) found that U.S. expenditures via farm and food tax preferences exceeded direct price and income support outlays in the late 1970s. Boyd and Newman analyze the impact of the 1986 Tax

Reform Act on agriculture and forestry activities in the U.S. They show that partial equilibrium analyses have tended to overstate these effects of this set of policies.

While the methods of agricultural intervention vary widely across countries, there is a strong tendency for the overall incentive effect to move from taxation in lower income countries to subsidization in wealthier countries (Anderson and Hayami). This dynamic feature of farm policies is strikingly illustrated by the case of Korea which moved from a position of net agricultural taxation to some of the world's highest subsidy levels in the course of the last three decades (Vincent, 1989a).

As a result of this broad pattern of intervention, the equilibrium ratio of agricultural to nonagricultural marginal value products for factors of uniform quality, evaluated at world prices, tends to exceed one in the LDCs, falling below one in the DME's. Thus incremental policies, or exogenous shocks, which result in resources moving into agriculture tend to be welfare-improving in the LDCs, while aggregate welfare is generally reduced by such an intervention in countries such as the U.S., Japan and the EC. This is dramatically illustrated by Tower and Loo, who show how the presence of such pre-existing distortions can translate into substantial increases in LDC incomes, following removal of DME support for agriculture. This follows from the fact that rising world prices for farm products serve to retain LDC resources in agriculture, where their marginal value product of world prices is relatively higher.

In sum, appropriate modeling of agricultural policies is an important, but difficult task. There is much to be gained by focussing on a particular policy and doing a good job of modeling it. In other cases it will be useful to incorporate a relatively complete set of economywide distortions in order to analyze the consequences of potentially second-best interventions. In these instances simplification will be required. However, this is no different than is required of traditional models of tax and trade policy, such as those reviewed in the chapters by John Whalley and Yolanda Henderson, elsewhere in this volume.

VIII. Product Differentiation and Imperfect Competition

The theme of product differentiation has come to play an increasingly important role in CGE analyses. For example, it is very common to adopt the Armington assumption that internationally traded products are differentiated by country of origin. This permits modelers to accommodate the phenomenon of two-way trade flows and prevents specialization from occurring. It is also common for models of imperfect competition to be premised on some sort of product differentiation which confers market power on individual firms within an industry. Thus it is relevant to consider the extent to which such assumptions are valid and useful for modeling agriculture and related industries.[17]

Agricultural Product Differentiation: What is the Evidence?

The world price effects of agricultural trade policy shocks depend importantly on the degree of product differentiation in these agricultural markets. There is a growing body of literature reporting estimated elasticities of substitution among agricultural imports, where products are differentiated by country of origin. In a recently completed Ph.D. dissertation, Kim Hjort estimates two levels of CDE import demand equations for wheat, in 130 countries. At the first level, the importer substitutes among alternative classes of wheat. Due to differences in physical characteristics, some wheat is altogether inappropriate for certain end uses, while other uses may call for a blend of varieties. The second level of importer decision making involves choosing among suppliers (countries) in order to satisfy the demand for a given class of wheat. Due to climatic factors, production of some classes of wheat is limited to a few regions of the world.

Hjort reports a number of findings worthy of note. First of all, some importers restrict themselves to a particular class/supplier of wheat, regardless of relative price movements. In short, non-price considerations often play an important role in determining wheat imports. Partly as a result of such specialization, aggregation of countries up to the regional level gives a false sense of supplier competition. Even in some of the countries where multiple suppliers are being used, responsiveness to relative price changes was surprisingly low.

Overall results on the elasticity of substitution (σ) among classes of wheat, and among suppliers within a class, are summarized by constructing weighted averages across importing regions, where weights are based on import volumes. Average σ values for between-class substitution range from -1.5 (i.e., complementarity) to 17.1. At the supplier level, weighted averages of σ range from -1.8 to 23.8. Based on Patterson's CES Armington model for wheat, Hjort chooses $\sigma = 10$ as the cut-off value for which product differentiation might make a significant difference in policy analysis.[18] By this criterion, about half of the estimated inter-supplier substitution relationships might be effectively approximated with a homogeneous products model. The remainder require some sort of differentiated products structure. Of course the true model may be more general than the homothetic formulation used in most such studies. Alston, Carter, Green, and Pick test the homotheticity restriction for wheat and cotton imports in selected countries using a nonparametric approach and reject it in every case.

An important consideration for CGE modelers using a differentiated products specification in a multiregion model is the potential for extremely large terms of trade effects (Whalley). This point has been further explored by Brown (1987) who concludes that these terms of trade effects are the direct consequence of the monopoly power conferred upon individual countries in these models. As a result, it becomes important whether or not such market power has already been exploited in the initial equilibrium position. The predominance of state trading organizations in international agricultural trade has given rise to a literature investigating the degree to which such market power is exercised (e.g., Thursby and Thursby). These issues deserve close attention, since models of national product differentiation which assume perfect competition can easily give results whereby the terms of trade effects dominate efficiency gains or losses (Brown and Stern).[19]

Product Differentiation and Market Power in the Food Industry

There is considerably more potential for product differentiation in the case of the food processing sectors' outputs. In his CGE model of the U.S. economy, Peterson distinguishes between three strategic groups in food manufacturing. The first includes those producing industrial goods (e.g., grain milling, sugar refining, fats and oils). These firms sell standardized products and deal with professional buyers, both of which are features that tend to severely circumscribe the potential for exercising market power. In contrast the second group of firms -- those selling advertised consumer goods -- are in a much stronger position. In some cases (e.g., breakfast cereals), these industries are highly concentrated. They are able to substantially differentiate their products, and entry into such a market can require a very high level of advertising expenditure. The third category of food manufacturing products which Peterson identifies are private-label or unlabeled goods (e.g., fluid milk). While they too are consumer goods, advertising intensities here are low and the buyers of these products are food retailers or grocery wholesalers.

Peterson models pricing behavior in the first and the third groups using the assumption of perfect competition. In the second group, individual firms determine an optimal markup, based on the perceived demand elasticity for their product. Advertising expenditures are taken as a proxy for fixed costs, and marginal costs are assumed constant. This gives rise to declining average costs in these imperfectly competitive sectors.

While firm-level product differentiation is more significant, the issue of product differentiation by region is less important in food manufacturing, as opposed to primary agricultural products. For example, certain types of wheat can only be grown in temperate climates, yet food processing facilities -- and hence food products -- are not geographically tied. In fact, due to transportation costs and the need to adapt to local tastes, there is relatively little trade in processed food products. As soon as a market reaches a critical size, firms typically shift the location of production, thus eliminating international trade in processed food (Martinez). In effect, foreign investment substitutes for trade.

IX. Summary and Directions for Future Research

As noted in the introduction, this paper may be viewed as a survey of agriculturally related attempts to meet some of the "hidden challenges" outlined by John Whalley. I am happy to report that progress has been made! There is little doubt that we are moving beyond the era in which general purpose CGE models will be employed to analyze issues specific to farm and food policies. Future modeling efforts might usefully address a number of the limitations raised in this paper.

First, all CGE research benefits from an improved data base and better parameter estimates. However, it is incumbent upon CGE modelers to help focus future applied econometric research on those areas which are likely to be most important for policy analysis. Indiscriminate calls for "better data" or "better parameters" will fall on deaf ears. In some cases the outcome of policy analysis will not hinge crucially on the assumed values for most of the model's parameters. We need to utilize systematic sensitivity analysis (as outlined in the chapter of Bernheim, Scholz, and Shoven, elsewhere in this volume) to demonstrate the benefits of obtaining new information and to draw attention to those cases where current research resources are misplaced.

Secondly, in my view much of the "farm problem" as well as the debate over farm, food and agricultural trade policy really comes down to issues about factor markets and their adjustment (or rather the lack of it). Further attempts to enrich the structure of CGE models in this dimension strike me as being very valuable indeed.

A third area for future research involves more explicit modeling of farm and food policies. While I discussed the modeling voluntary programs at some length in this chapter, there are many other policies which would benefit from more careful representation. Quantitative restrictions, price ceilings and floors, and stock release rules are all common types of farm sector interventions which lend themselves to explicit treatment in a CGE framework. Furthermore, as Clarete and Whalley have shown, the interaction of such policies with other domestic distortions can give rise to dramatically different welfare effects.

Perhaps the biggest void in existing CGE models targeted at agricultural policy questions is in their treatment of the food manufacturing and marketing sectors. In the U.S. only about $.30 of every dollar spent on food goes to the farmer. Value-added in food manufacturing is roughly equal to that in agriculture. As these industries become increasingly concentrated, the potential for imperfect competition increases, as does the industries' ability to influence farm and food policy. It is imperative that the role of these actors be addressed in future economywide analyses of agricultural issues.

Finally, there is the question of multi-region vs. one country CGE analysis. Given the important role of agriculture in international trade and trade policy, there is a real need for models which can address farm (and nonfarm) policies at a relevant level of disaggregation, in a multilateral environment. There are numerous efforts proceeding in this direction.[20] However, data remains a big obstacle. Progress would be greatly facilitated by the development of a common CGE trade data base, from which all could draw and into which all could contribute.[21] This takes us back to another one of John Whalley's "hidden challenges" -- namely the need for CGE modeling teams. If we are going to make significant progress towards the alleviation of these model limitations in the near future, collaboration in research, and the sharing of data and parameters, will be of the utmost importance.

Footnotes

[1] In this chapter I will focus primarily on research related to the developed market economics (DMEs), with a particularly heavy reliance on U.S. examples. A separate chapter in this volume will deal with CGE applications in the developing countries.

[2] A notable exception is provided by the ORANI experience in Australia (Dixon, et al.) which has been strongly influenced by economists with an interest in agriculture.

[3] See, for example, the agricultural policy text by Bruce Gardner (1988).

[4] Unilateral agricultural reform in the U.S. results in dairy and sugar imports increasing dramatically, which in turn causes world prices to rise. In order to address this problem, Hertel, Thompson and Tsigas choose values for the Armington parameters associated with dairy and sugar imports such that elimination of the world-domestic price differential for these products results in the same change in imports as is predicted by USDA's partial equilibrium trade model under the same experiment. Kilkenny and Robinson (1989) work with a more aggregate model and do not adjust for world price changes in the unilateral case, but they do make an adjustment in what they term their "multilateral" liberalization scenario. (They too, rely on USDA's partial equilibrium trade model for this purpose.)

[5] In fact this is precisely the type of non-convexity which Ball (1988) encountered prior to imposition of curvature restrictions on his aggregate, multiproduct profit function for U.S. agriculture. Own-price effects were too small, relative to off-diagonal responses. By imposing curvature, he essentially forced more of the price responsiveness "onto the diagonal" (personal communication with V.E. Ball).

[6] Stoeckel (1985) introduces a distinction between small and large scale farming into his CCE model of the EC. Since he calibrates the model to changes over the 1973-83 period, this is probably a necessary feature for purposes replicating observed changes in the farm sector.

[7] For example, returns to farm real estate (1947-84) exhibited a standard deviation double that of residential real estate (Irwin, Forster, and Sherrick, table 1).

[8] See, for example, Higgs (1986), Figure 3.1.

[9] The problem in estimating (e.g.) an indirect utility function directly is that time series data on budget shares for this group of commodities is unavailable. Thus, price and quantity indices are used to estimate a demand system with neoclassical restrictions imposed only at base period budget shares (see Huang and Haidacher).

[10] Evidence from dynamic econometric models estimated using post-WWII data for U.S. agriculture find that labor is the most sluggish in adjusting to a shock. For example, setting all factors at their long-run equilibrium levels, Vasavada and Chambers find that first-year adjustments in labor, capital, materials, and land are 5%, 26%, 63%, and 66%, respectively. Schuh (p. 806) argues that the farm labor force is becoming increasingly integrated with its nonfarm counterpart and future adjustments in this factor are likely to be more rapid. However, recent work by Thompson and Martin finds that the role of the nonfarm sector in determining farm labor supply has diminished in recent years. One explanation for this phenomenon is the increasing importance of illegal aliens in the hired labor market. Unlike their legal counterparts, these workers are relatively isolated from the nonfarm economy.

[11] Such problems of interpretation led Griliches (1960) to advocate an indirect approach, to estimating supply response. Using factor demand relationships he estimated a longrun supply elasticity of between 1.2 and 1.3.

[12] This is the so-called "normal case" where the expansion effect associated with raising all prices simultaneously dominates the interproduct transformation effects (Sakai).

[13] This relationship between relative prices and cost shares implies a long run value of σ in excess of one.

14 I have explored this relationship between technology, factor mobility, and supply response in the case of U.S. agriculture (Hertel 1989). I begin with the estimation of a multiproduct translog cost function. I then show how the aggregate agricultural sector supply elasticity may be derived, based on alternative factor mobility assumptions, from an estimated matrix of Allen (output-constant) partial elasticities of substitution. Two specific cases are considered. In the first, land and capital are assumed fixed and aggregate farm labor (hired and own-labor) is partially mobile with a supply elasticity of 0.5. This generates a supply elasticity of 0.84. In the second case, with labor and capital perfectly mobile, the aggregate supply elasticity is simply equal to the absolute value of the own-Allen partial elasticity of substitution for land, which is estimated to be 3.2.

15 This striking statistic is largely due to the mountainous nature of the country and the fact that major cities have been located in flat, prime agricultural lands.

16 For example, Rutherford, Whalley, and Wigle have examined the capitalization effects of the U.S. wheat program. They conclude that the conditional nature of program participation results in dilution of such capitalization effects. This is most dramatic for those farms which are drawn into the program at the margin. In this case the benefits of a more generous program are largely dissipated in higher costs of complying with the acreage set-aside requirement. By contrast, capitalization effects for inframarginal participants -- those who were already in the program -- are nearly one dollar for each additional dollar transferred to those farmers.

17 This was the topic of a recent conference sponsored by the International Agricultural Trade Research Consortium. The interested reader is referred to Part One of the volume edited by Carter, McCalla, and Sharples.

18 Patterson finds that the export demand elasticity for U.S. wheat is -0.78 in the absence of product differentiation -- or using an Armington parameter of $\sigma = 100$. However, if σ is set as low as 10, this elasticity

is still relatively close (-0.73). Reducing σ to 3 and then 1 results in export demand elasticities of -0.61 and -0.41.

19 One "fix" for this problem is to differentiate exports and domestic goods, as suggested by de Melo and Robinson. However, this specification may also introduce undesirable side-effects, as it drives a permanent wedge between domestic and export prices.

20 Of particular note are: the WALRAS model developed at the OECD (OECD, 1990), the SALTER model developed at the Australian Industries Commission (Industries Commission, 1991), and the RUNS model developed at the OECD Development Centre (Burniaux and van der Mensbrugghe).

21 For an example of such a data base see the paper by Nguyen, Perroni, and Wigle.

Appendix. Illustrating the Limitations of General Purpose CGE Models of Agricultural Policies

In order to illustrate the limitations of general purpose models in the analysis of agricultural policies, I have chosen to analyze the economywide effects of agricultural supply control under alternate model specifications. I will begin with a specialized "base" model outlined in Hertel, Ball, Huang, and Tsigas. This model will be subsequently restricted in order to illustrate the effects of various parametric restrictions common to general purpose CGE models. The base model incorporates econometric evidence on the farm and food sector into a linearized general equilibrium model of the U.S. economy. This model has 41 sectors of which about half correspond to farm and food production activities. Private domestic nonfood consumption is assumed separable from food consumption and the latter is disaggregated into eight composite goods. This complete, unrestricted demand system is estimated with homogeneity, symmetry, and Engel aggregation imposed. Thus there are 36 independent price elasticities and 8 independent income elasticities of demand in this system. Foreign household preferences for farm and food products are calibrated to replicate four-year export demand elasticities taken from Seeley.

Constant returns to scale are assumed in all sectors, including agriculture, where the estimated production technology permits substitution among six composite inputs, including: land, labor, crop capital, livestock capital, feed, fertilizer and chemicals, and all other inputs. Other sectors are characterized by a CES primary factor aggregate. In addition, technologies in the food marketing sectors introduce substitution between selected raw farm products and marketing inputs. These parameters are based on the work of Wohlgenant (1989). Yet another source of intermediate input substitution occurs in the construction of a composite feed input for the livestock sectors. Here producers substitute among alternative feed ingredients, based on a nested-CES technology.

The particular features of this special-purpose CGE model contrast sharply with many one-country CGE models which: (a) do not utilize flexible functional forms to estimate producer technology and consumer preferences, (b) do not permit substitution in intermediate uses, and (c) do not introduce cross-price elasticities of export demand. Admittedly there are instances where one or more of these features may not be critical. However, it is my contention that they will generally play an important role in the analysis of agricultural policies. They thus serve to illustrate how a special purpose model might begin to differ from its general purpose counterparts.

By way of example, consider the implications of supply control legislation proposed in 1986 by Senator Harkin and others (Harkin, et al.). One of the objectives of this legislation was to raise farm prices of U.S. grains, oilseeds, and cotton by further voluntary restrictions in planted acreage. This government intervention is introduced as a marginal change in the pre-existing policy environment in 1984. Selected results are presented in the first column of table A1. These estimates are based on the behavioral specifications discussed above, and it is termed the base case (model 1). Models 2-5 illustrate the implications of utilizing various aspects of a "general purpose" CGE model to analyze this issue.

In the base case, sufficient acreage is bid out of food grain, feedgrain, oilseeds, and cotton production to raise market prices for these crops by 10% over their 1984 levels. The size of the requisite output reduction is determined by the farm level demand elasticities for these products. The presence of significant cross-price effects at the farm level, resulting from substitution in U.S. demands and rest-of-world demands and supplies, means that it is much easier to raise prices of these products in unison, as opposed to individually. The share weighted sum of these total elasticities for the four controlled crops is reported as the farm level demand elasticity in the second row of table A1.

With nonland inputs mobile, the benefits of the 10% commodity price increases for controlled crops must reside in land rents. As a result returns to land increase by 26% across all models. (This is driven by the cost shares of land and is largely independent of the elasticities assumed.) In the base case, nonland inputs (especially fertilizer) are substituted for the increasingly scarce land, and per acre yields increase. The global welfare cost of this

Table A1. Limitations of General Purpose CGE Models for the Analysis of Acreage Controls in U.S. Agriculture.[a]

	Model 1 (Base Case)	Model 2 (CD)	Model 3 (NCP)	Model 4 (LII)	Model 5 (CD/NCP /LII)
Farm Level Demand Elasticity-					
- all product prices rise	-.50	-.70	-.61	-.32	-.62
- controlled product prices rise	-.55	-.59	-.80	-.38	-.67
Payment Crop Output (% change):					
- foodgrain	-2.4	-2.6	-8.8	-2.4	-9.2
- feedgrain	-5.7	-6.3	-7.8	-2.7	-5.5
- oilseeds	-4.5	-4.8	-6.7	-5.0	-7.5
- cotton	-9.7	-9.8	-9.5	-9.9	-9.8
Factor Employment (% change):					
- farm labor	-2.7	-3.2	-3.4	1.0	-0.2
- crop capital	-5.1	-5.4	-6.9	4.0	1.8
- fertilizer	1.4	0.9	-0.9	-2.7	-5.5
- cropland planted	-11.2	-11.5	-13.5	-13.6	-16.4
Land Rental Rage (% change):	26.8	26.6	26.7	26.5	26.3
Global Welfare Change					
(millions of 1987 dollars)	-2,592	-2,691	-3,256	-3,405	-4,152

[a] Application of the base case model to a variety of supply control alternatives is reported in Hertel and Tsigas (1991).

program is very high indeed. It amounts to $2.6 billion and reflects primarily the cost of idling productive resources -- as well as the ensuing (excessive) intensification of production on the remaining cropland.

The first alternative model in table A1 involves the use of Cobb-Douglas (CD) preferences for domestic private households. The implied unitary consumer demand elasticities for food products are far too large, and result in an overstatement of the aggregate farm level demand elasticity for all products (the first row in table A1). However, since the subset of products affected by supply controls are largely exported or employed as intermediate inputs, the aggregated farm level demand elasticity with respect to just these four prices is little affected (row 2). The biggest differences are for feedgrains and oilseeds. By overstating the consumer's price elasticity of demand for livestock products, model 2 overstates the size of the requisite supply reduction of these feedstuffs. As a consequence, more land must be idled and the global welfare loss is overstated.

In the next column of table A1 (model 3), cross-price effects in export demand are eliminated (NCP), but preferences are no longer restricted to be Cobb-Douglas. By ignoring grain and oilseed substitution in the rest of the world, this model calls for an excessive reduction in the supply of these products and the welfare loss is overstated by 25%.

The final individual restriction considered in table A1 is the imposition of Leontief intermediate input usage (LII). Thus farm products no longer substitute for one another (or for other inputs) in the food processing sectors. As a result, the farm level demand elasticities for agricultural products are too small, which means the model calls for lesser supply reductions than in the base case. However, there is another important consideration at work here. Since intermediate inputs (e.g., fertilizer) at the farm level no longer substitute for land, their usage will fall in proportion to output. Whether or not the amount of idled land falls or rises relative to the base case depends on the potential for substituting towards labor and capital within the primary factor aggregate. (Such an aggregate does not exist in model 1, since the farm level technology is unrestricted.) Most general purpose models assume some convenient functional form to represent the primary factor aggregate. This is itself an important limitation when three factors are present (Hertel, 1988). For purposes of illustration, I follow Robinson, Kilkenny, and Adelman, and Kilkenny and Robinson (1988 and 1989) and impose a Cobb-Douglas value-added function for purposes of aggregating capital, labor and land in the farm sector. This results in too much substitution of labor and capital for land. As a consequence, despite the lower farm level demand elasticity and despite the absence of purchased input substitution for land, more acreage must be idled in model 4 and the welfare cost is once again overstated, relative to the base case.

The final column in table A1 reports results based on the simultaneous imposition of restrictions CD, NCP, and LII. Some of these effects are offsetting -- for example the impact of CD and NCP on the farm level demand elasticities is opposite that of LII. However, all of the restrictions lead to an overstatement of the necessary acreage reduction. The combined effect is to overestimate welfare costs (relative to the base model) by 60%.

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