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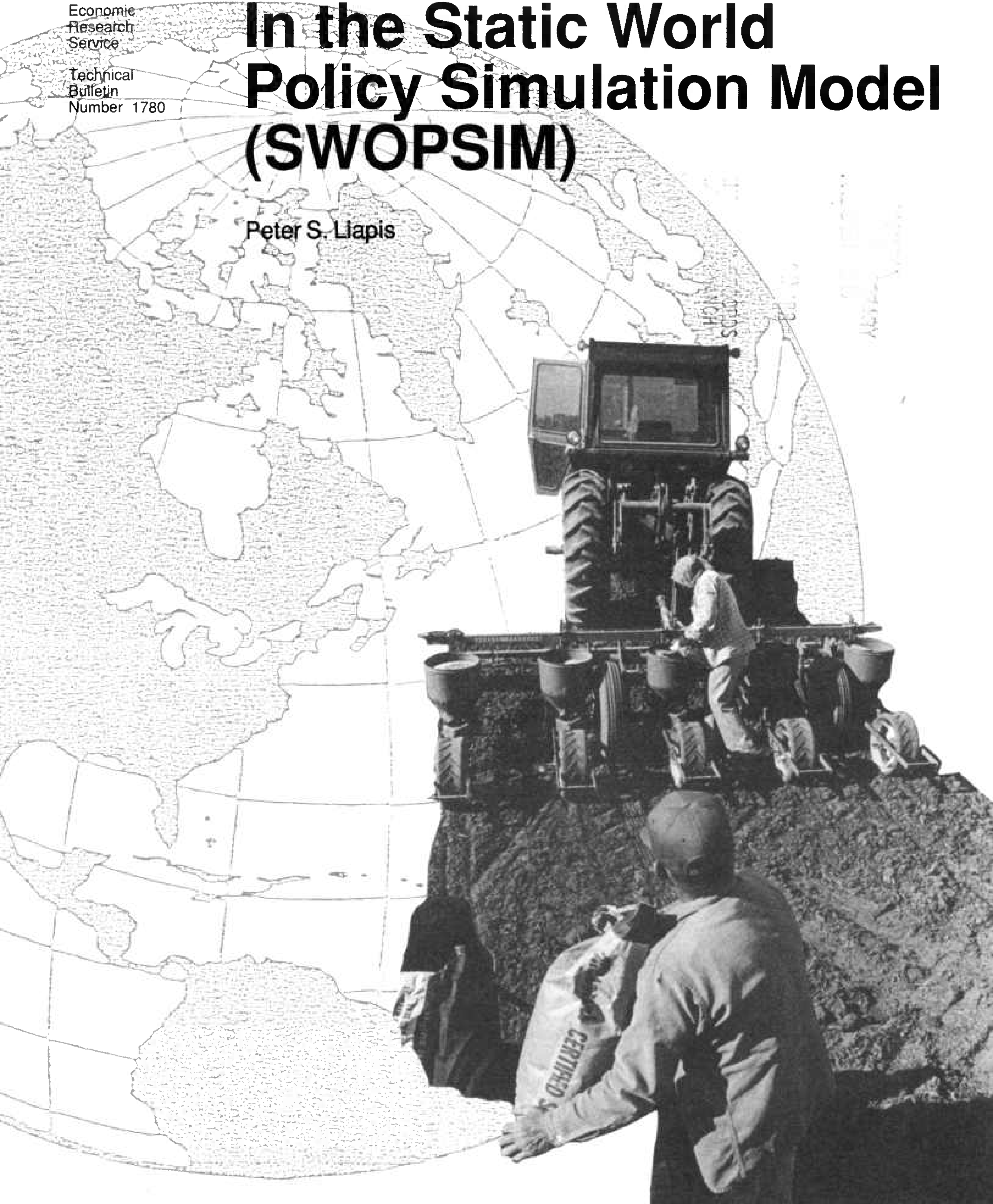
Incorporating Inputs In the Static World Policy Simulation Model (SWOPSIM)

Peter S. Liapis



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Incorporating Inputs in the Static World Policy Simulation Model (SWOPSIM). By Peter S. Liapis. Agriculture and Trade Analysis Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1780.

Abstract

SWOPSIM models have been used to analyze trade liberalization scenarios. However, the analysis is silent regarding the impacts of trade liberalization on the demand for factors of production. An aggregate multiple-output profit function for U.S. agriculture was used to include factors of production in the SWOPSIM modeling framework. The methodology used to incorporate inputs also enabled the generation of a set of output supply elasticities which are consistent with econometrically estimated aggregate elasticities and the theory of the profit-maximizing firm. Several scenarios were run to examine the sensitivity of the model to the new set of elasticities and to demonstrate the added insights provided by including factors of production in the analysis. As expected, the demand for inputs is sensitive to the specific output prices that are exogenously changed.

Keywords: Trade, static model, policy simulation, multiple-output technology, inputs, elasticities

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Summary

Multiple-output technology was used to produce a matrix of output supply and input demand elasticities that were then used to generate the Static World Policy Simulation Model's (SWOPSIM) U.S. country model. The advantages of employing this methodology to create the elasticities rather than the *ad hoc* method previously used are: (1) production technology is explicitly incorporated in the elasticity structure; (2) output supply elasticities are derived from a single econometrically estimated set of elasticities rather than from various different sources; and (3) inputs are explicitly incorporated in the analysis and in a manner consistent with theory.

SWOPSIM was used to generate two models, INPUTS and CURRENT, consisting of two regions, the United States and the rest of the world. The INPUTS model consists of the supply elasticities generated from the methodology presented in this paper and includes six factors of production. The CURRENT model consists of the elasticities presently used in the U.S. country model. In this model, the demand for primary factors of production is excluded. The methodology used to obtain disaggregate elasticities enabled many of the output supply elasticities in the two models to be the same. The rest of the world and consumer demand elasticities are also the same in both models.

Results from three simulations indicate that INPUTS, a model built from a consistent set of econometrically estimated elasticities and explicit economic structure, yielded results on output supplies and prices that were similar to the results from the CURRENT model. This has at least two implications. First, possible criticisms of CURRENT structure--that it is *ad hoc*, that it is without economic structure, and that it is inconsistent with theory--may not be valid. If resources or data are not available to modify many of the country models, trade liberalization results based on this structure may be reasonable. The other implication is that the INPUTS structure provides results that are consistent with CURRENT while also providing information on factors of production, information that is lacking in CURRENT. If resources and data are available, this approach should be pursued because it is derived from an explicit economic structure and it is consistent with the behavioral assumption of profit maximization. Furthermore, the demand for factors of production can be ascertained.

Incorporating Inputs in the Static World Policy Simulation Model (SWOPSIM)

Peter S. Liapis

Introduction

Several multicommodity, multicountry models have been developed to analyze effects of agricultural trade liberalization (13, 15, 16, 19, among others).[1] These models generally specify production as a function of the prices of outputs and only a few variable input prices. Furthermore, the underlying production technology is generally not explicitly specified, and output supply elasticities are assembled from a variety of sources.

Since these models do not explicitly include the demand for factors of production, trade liberalization analysis based on these models is deficient because explicit statements regarding farm income, or the demand for productive factors such as labor or capital, cannot be made.

Researchers at the Organization for Economic Cooperation and Development have recognized this deficiency and are in the process of modifying their Ministerial Trade Mandate model to include inputs. Others have also attempted to rectify these deficiencies by incorporating inputs (12, 20). This report documents the methodology used to incorporate inputs in the trade liberalization models built with the Static World Policy Simulation Model (SWOPSIM).

The focus of this report is to provide economic structure to the production side of SWOPSIM while expanding the commodity set to encompass factors of production. The methodology is based on the assumption that U.S. agriculture is characterized by a multiple-output profit function, which enabled me to assimilate inputs in a theoretically consistent manner. In the process, I derived a set of output supply and input demand elasticities which are consistent with neoclassical production theory of a profit-maximizing firm. Thus, the emphasis is on the production structure of U.S. agriculture, not on analyzing input markets.

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[1] Underscored numbers in parentheses refer to literature cited in the References section at the end of this report.

SWOPSIM Model Structure

SWOPSIM is a flexible modeling framework which can be used to create single- or multiple-commodity models for two or more countries or regions (14). The models can be used to determine production, consumption, and net trade from exogenous changes in supply, demand, and/or policy. The models are created in a spreadsheet and, as such, are easily understandable and can be readily modified to the needs of individual researchers.

SWOPSIM's structure is based on constant elasticity functional forms for agricultural output supplies and consumer demands. The models created in the SWOPSIM framework are static. The models assume that agricultural markets are in equilibrium in the base year and are solved to determine changes from the base due to exogenous shocks such as changes in demand, supply, or policy. The framework of the analysis is comparative statics; consequently, the time path of the endogenous variables is not part of the solution. The new equilibrium solution is assumed to occur following the necessary adjustment period (about 5 years). The models, although extensive in their agricultural commodity coverage, do not include primary factors of production, nor do they include nonagricultural sectors; therefore, they are partial equilibrium models.

Trade is the difference between domestic demand and supply, and the models do not differentiate between domestically produced or imported commodities. Exchange rates are used to translate world prices to trade prices which are then linked to producer and consumer prices in domestic currency. Therefore, they are net-trade models and employ the law of one price to solve for a world price which balances agricultural imports with exports.

The policy structure of SWOPSIM is embedded in equations linking domestic and international prices. Policies are inserted as subsidy equivalents at the producer, consumer, export, or import level and, as such, can affect production, consumption, and trade. Price transmission elasticities are used to indicate the degree of responsiveness of domestic prices to international prices. The primary use of the model has been to determine the implications on production, consumption, and trade, when these policy measures are eliminated (15, 16). Details on the economic and policy structure embedded in the model can be found in Dixit and Roningen (4), and Roningen (14).

Elasticities in SWOPSIM

Aside from policy measures, the basic parameters that drive the models are the output supply and consumer demand elasticities. The full version of SWOPSIM includes 22 agricultural commodities. Therefore, each country/region model contains a 22x22 matrix of output supply elasticities and a 22x22 matrix of consumer demand elasticities.

These elasticities have not been estimated directly because data requirements make it an almost impossible task. Consequently, SWOPSIM is a synthetic model; output supply and consumer demand elasticities were obtained from a variety of published sources, or based on expert opinion.[2] However, assimilating elasticities from a variety of sources that used different estimation procedures, different data, different time periods of observation, different objectives, and linking them in a simulation model (although necessary because of data, time, or other constraints) has the potential of resulting in a system with supply elasticities for a given country/region which are theoretically inconsistent with behavioral relationships.

Most of the elasticities used to construct SWOPSIM models were obtained from sources that estimated supply response in a rather ad hoc fashion; usually by estimating single-equation single-output supply functions to determine output response. In these approaches, the theory of the firm does not play a significant role in specification and estimation of the models. Behavioral assumptions (such as profit maximization or cost minimization) are not formally incorporated (3, 11).

A possible criticism of the SWOPSIM framework (and other synthetic trade models) is the lack of economic structure. The elasticities employed are generally in a reduced form and cannot be related back to specific assumptions about production technology. The current version of SWOPSIM does not include factors of production. Therefore, effects of output price changes on the demand for inputs are not known. The implications of trade liberalization on agricultural employment, on capital use in agriculture, or on the demand for the other factors of production are also not discernible given the present SWOPSIM structure.

A more structured approach to obtaining elasticity estimates is based on duality theory using either profit, revenue, or cost functions. The dual approach to estimating elasticities begins with the theory of the firm--assuming profit or revenue maximization or cost minimization--derives output supply and/or input demand relationships. This method provides a link between theory and empirical estimation, and it provides theoretical restrictions on the behavior of supply and demand equations that can be econometrically tested. Furthermore, this approach explicitly incorporates the production technology, and relationships, such as degree of substitutability among inputs or economies to scale, can be determined.

Using the duality theory to derive elasticities for SWOPSIM models allows the explicit incorporation of the production technology in the elasticity structure. In addition to obtaining output supply elasticities which are consistent with behavioral assumptions such as profit maximization, the approach allows the

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[2] A complete description of the supply and demand elasticities used in SWOPSIM are contained in (6).

expansion of the commodity set to include factors of production. Furthermore, whereas presently SWOPSIM is silent regarding the impacts of output movements on input demands, a version which includes inputs will be able to determine implications on demand for labor, capital, and other factors of production due to policy or other exogenous changes. In modeling policies for countries or regions where data are available, elasticities derived from a production function or from the dual-profit, revenue, or cost function should be preferred to the elasticities from the *ad hoc* procedures.

This paper demonstrates the methodology used to incorporate factors of production in the SWOPSIM modeling framework. The methodology is based on duality theory and its use is illustrated by incorporating the factors of production in the U.S. country model. The procedure used to add inputs to SWOPSIM also enables the derivation of output supply and input demand elasticities which are consistent with the neoclassical theory of the multiple-output firm assuming profit maximization.

Input demand elasticities were econometrically estimated by Ball (1). These elasticities, however, are based on a multiple-output profit function which contains relatively aggregate commodity groupings compared with the disaggregate commodities used in SWOPSIM. The methodology employed bridges the gap by enabling the disaggregation of Ball's econometrically estimated elasticities. These disaggregated elasticities are consistent with the econometrically estimated aggregate elasticities and the theory of the multiple-output firm that maximizes profits. In the disaggregation process, I demonstrate that many of the output supply elasticities that are in SWOPSIM's U.S. country model are consistent with the econometrically derived aggregate elasticities estimated by Ball (1).

This analysis is not the first to use multiple-output technology to derive elasticity relationships in SWOPSIM. Haley (7) employed the results of the multiple-output profit function to derive elasticities for dairy and oilseeds. This analysis differs from his in several ways. First, this analysis expands the commodity set in SWOPSIM to incorporate factors of production such as labor and capital. Second, the disaggregate elasticities derived in this analysis are consistent with econometrically estimated aggregate elasticities. Third, Haley's analysis focused on jointness in outputs (one input, milk for example, producing three outputs), whereas the current analysis focuses on jointness in inputs. Last, Haley implicitly assumed nonjointness in inputs between dairy, oilseeds, and the other commodities in SWOPSIM by specifying different profit functions for soybeans and dairy.

The rest of the paper is organized as follows. The multiple-output profit function is briefly reviewed and relationships which are germane to the purpose of this paper are derived. The methodology is then applied to obtain output supply and input demand elasticities which are used to construct a new U.S. model. Finally, several experiments are simulated to compare and contrast the results from the new model relative to the results from the original model. The results indicate that the two models provide similar solutions, but the new model also provides information on input demands which is not available from the original SWOPSIM structure.

Review of Theory

In this section, some of the more relevant features (for the purpose on hand) of the multiple-output profit function are reviewed. The discussion also briefly touches upon the notion of flexible functional forms, separability, and nonjointness, concepts germane to the purpose of this paper. The discussion is primarily based on information from Chambers (2), Hertel (8), and Ball (1), although many other sources are available. The discussion here is by no means all-inclusive. The interested reader is encouraged to refer to the above-mentioned sources for a more rigorous and technical discussion. The primary purpose of this review is to set the stage for obtaining the elasticities in the SWOPSIM framework from a set of econometrically estimated elasticities which are consistent with the theory of the multiple-output firm under profit maximization.

The motivation for analyzing U.S. agricultural production in a multiple production framework is the recent work by Ball (1); and Shumway, Saez, and Gottret (17). They note that agricultural firms produce more than a single output; for example, grains and livestock are jointly produced by many farms. Agricultural supply response analysis, therefore, should incorporate this feature of technology rather than use single-output methods to derive supply responses.

Production technology can be specified by relating a vector of outputs to a vector of inputs. Duality theory states that the same information on the underlying production technology can be obtained by specifying a profit, revenue, or cost function which uses prices rather than quantities to determine relationships. Dual methods translate technical relationships into behavioral ones. Early research (prior to the 1970's) tended to estimate production functions while research since then has mostly employed the dual approach.

The multiple-output technology is assumed to consist of m outputs, $Y = (y_1,...,y_m)$, and n inputs, $X = (x_1,...,x_n)$. The firm has a production possibility set, T, which is the set of all input-output bundles compatible with the technology given to it. T is assumed to be nonempty, closed, bounded from above, and convex. Letting $P = (p_1,...,p_m)$ denote a vector of m exogenous output prices (all positive real numbers), and $W = (w_1,...,w_n)$ denote a vector of n exogenous variable input prices (all positive real numbers), the multiproduct profit function which corresponds to T is:

$$\pi(P, W) = \max_{Y,X} \{P*Y - W*X : (Y, -X) \epsilon T\} \tag{1}$$

Given the assumptions made on T, the profit function $\pi(\cdot)$ is linearly homogeneous in output and variable input prices, convex in prices, continuous and twice differentiable. Under these conditions, Hotelling's lemma defines m profit-maximizing output supply functions:

$$\partial\pi(P,W)/\partial p_i = Y_i(P,W) \qquad i = 1,\ldots,m, \tag{2}$$

and n profit-maximizing input demand functions,

$$\partial\pi(P,W)/\partial w_j = -X_j(P,W) \qquad j = 1,\ldots,n. \tag{3}$$

Using the fact that the profit function is twice differentiable and Young's theorem provide the following symmetry conditions:[3]

$$\partial X_i/\partial w_j = \partial X_j/\partial w_i \qquad \text{for all } i,\ j, \tag{4}$$

$$\partial Y_s/\partial p_t = \partial Y_t/\partial p_s \qquad \text{for all } s,\ t, \tag{5}$$

$$\partial X_i/\partial p_s = -\partial Y_s/\partial w_i \qquad \text{for any } i,\ s. \tag{6}$$

The linear homogeneity of the profit function, Hotelling's lemma, and Euler's theorem imply that the optimum output supply and input demand functions are homogeneous of degree zero. Multiplying all output and input prices by a constant (greater than zero) does not affect optimum output supplies or factor demands:

$$\sum_{j=1}^{n} w_j\ \partial X_i/\partial w_j + \sum_{t=1}^{m} p_t\ \partial X_i/\partial p_t = 0 \qquad \text{for any } i \tag{7}$$

$$\sum_{j=1}^{n} w_j\ \partial Y_s/\partial w_j + \sum_{t=1}^{m} p_t\ \partial Y_s/\partial p_t = 0 \qquad \text{for any } s. \tag{8}$$

The convexity of the profit function implies that its Hessian matrix is positive semi-definite. This in turn requires that $\partial X_i/\partial w_i \le 0$ and $\partial Y_s/\partial p_s \ge 0$; that is, input demand is downward sloping in its own price and output supply is upward sloping in its own price.

In addition, a "normal" technology fulfills the following conditions: (a) the marginal cost of an output tends to increase when the quantities of other outputs decrease or when the prices of inputs increase, (b) the marginal revenue of an input increases when the quantities of other inputs increase or when the price of outputs increase. These conditions imply the following set of restrictions on the technology:

$$\partial X_i/\partial w_j \le 0 \text{ for any } i,\ j; \quad \partial Y_s/\partial p_t \ge 0 \text{ for any } s,\ t, \tag{9}$$

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[3] To reduce notational clutter, the arguments of the function being differentiated have been dropped.

$$\partial X_i/\partial p_s \geq 0 \text{ for any } i, s; \quad \partial Y_s/\partial w_i \leq 0 \text{ for any } i, s. \qquad (10)$$

Condition (9) indicates that gross substitution among inputs and outputs is ruled out, while condition (10) assures that regressive relationships between inputs and outputs are ruled out.

The discussion above on the properties of the technology and the profit function is very general. Empirical implementation of the methodology requires discussion on the notions of separability, jointness, and functional form.

Separability enables the decomposition of a function such as profit, cost, or production into groups of subfunctions, and it allows the aggregation of the arguments of each subfunction. Several different types of functional separability have been discussed by economists, and each of them imposes some sort of structure on the general functional form. For example, the profit function in (1) consists of m outputs and n inputs. The assumption of weak separability in input and output prices implies that (1) can be written as:

$$\pi(P,W) = g(h_1(P), h_2(W)). \qquad (11)$$

This form of the profit function means that the output price vector and the input price vector have been aggregated into an output and an input price index, with h_1 and h_2 being the aggregator functions. Equation (11) suggests that the firm or the economy produces a single aggregate output using a single aggregate input. Equation (11) is one of many different representations of a separable profit function. The output price and/or the input price vectors can be decomposed into many different subfunctions to suit the needs at hand. For example, Ball's (1) profit function can be thought of as consisting of 11 aggregator subfunctions--5 outputs and 6 inputs, while Shumway, Saez, and Gottret (17) specified a profit function of 5 outputs and 4 inputs, or 9 aggregator subfunctions.

The assumption of separability imposes certain behavioral assumptions on the profit function. For example, separable profit function implies $((\partial\pi/\partial p_i)/(\partial\pi/\partial p_j))\ (\partial/\partial p_k) = 0;\ i, j \in h_1,\ k \notin h_1$. By Hotelling's lemma, this means that the optimal output (or input) level is invariant to the level of prices outside the subfunction. Separability also allows optimization by stages. First, one optimize's the individual subfunctions separately and then uses those results in the second stage to optimize the overall function. This is especially helpful in econometric estimation where the first stage is used to develop instrumental variables to use for the second stage (5). Optimization by stages reduces the number of equations and parameters that must be estimated simultaneously, thus simplifying the problem of modeling the multiple-output firm.

A firm that produces many outputs using many inputs may not necessarily have a production technology that is joint. Several different definitions of jointness or its complement, nonjointness, have been discussed in the literature (2, 10, 18). These definitions generally refer to either nonjointness in outputs or nonjointness in inputs. Each type of nonjointness imposes certain conditions on the multiple-output profit function.

Jointness in output usually refers to the case where a single input produces many outputs. In agriculture, this occurs frequently; for example, sheep produce both wool and mutton, cattle produce hide, meat, and offal, and soybeans produce meal and oil. For the multiple-output firm, nonjointness in outputs implies that the demand of one input does not respond to the level of another input's price; that is, $\partial^2\pi/\partial w_i \partial w_j = 0$ $(i \neq j)$. Therefore, the demand for each input can be modeled separately as a function of its own price and the output price vector. Shumway, Pope, and Nash (18) in their extensive discussion of jointness, however, state that at the usual level of aggregation, documented elasticities of substitution are nonzero, implying that nonjointness in outputs occurs so infrequently that it is of little interest to econometric applications.

The case most often discussed in the literature is nonjointness in inputs (usually the term is used without the qualifier, in inputs). For the multiple-output firm, technology is nonjoint in inputs if the optimal supply of one output does not depend upon the price of other outputs, that is, $\partial^2\pi/\partial p_i \partial p_j = 0$ $(i \neq j)$. Decisions about the production of one commodity are independent of similar decisions about other outputs; thus, one can model supply response using single-output rather than multiple-output approaches, without loss of generality.

The assumptions of separability and nonjointness provide behavioral postulates which can be tested empirically to determine their validity. Although not discussed here, the joint hypothesis of separable and nonjoint profit function provides conditions on the profit function which can also be tested empirically for their validity. For an example, see (1).

Another step toward empirical implementation of the methodology is to specify a functional form in order to estimate the relationships. The functional form also imposes some a priori restrictions on the technology. For example, using a Cobb-Douglas function to characterize the technology imposes on the technology the condition that the Allen elasticity of substitution is one. Awareness that the choice of functional form may impose false restrictions has led researchers to search for functional forms that contain enough parameters to portray all of the effects that they want to measure without imposing prior constraints.

For example, the functional form for the multiple-output profit function discussed above should be able to provide estimates of: (1) the level of the profit function, (2) the m output supply and n input demand relationships, and (3) the Hessian matrix. Functional forms that meet this criterion are called flexible functional forms. A function is flexible if it provides a second order approximation to an arbitrary twice differentiable function. The true profit function is not generally known; therefore, it must be approximated. Taylor's theorem is invoked to approximate the arbitrary and unknown profit function. The underlying true profit function is usually approximated as a second order Taylor series expansion. The three most commonly used flexible forms for estimating the true profit function are the translog, the quadratic, and the generalized Leontief.

To summarize, multiple-output production is the most general representation of technology. Duality theory states that specifying a multiple-output profit function provides the same information on the technology. Employing this methodology generates output supply and input demand functions and their associated elasticities which are theoretically consistent with the usual assumption of profit maximization. This is in contrast to the elasticities that are derived from the more ad hoc, single-equation methods which tend to lack economic structure and cannot be related back to specific assumptions about production technology. Although modeling multiple-output technology is more complex than the single-output case, modeling the multiple-output firm can be simplified by specifying separability (which allows aggregation of products), and/or by specifying nonjointness (which enables the use of single-product approaches). The advantage of starting with the multiple-output representation is that the validity of separability and/or nonjointness can be tested empirically rather than imposed a priori as the true representation of the production technology.

Applying the Theory to SWOPSIM

The current version of SWOPSIM contains 22 output commodities. Assuming that these commodities are produced with 6 inputs, a 28x28 matrix of output supply and input demand elasticities is needed to represent production. Using a flexible functional form for the multiple-output profit function, assuming joint production and imposing symmetry but not separability, in order to derive the needed elasticities, one needs to simultaneously estimate a system that contains 28 linear terms, 28 quadratic terms, and 378 interaction terms. Estimating such a large system is fraught with difficulties due to data limitations, multicollinearity, and lack of degrees of freedom. As far as I know, no one has estimated such a system. Estimating 28 separate equations independently would make estimation easier but would impose the assumption of nonjointness which abstracts from the multiple-output nature of U.S. agriculture. Because of these difficulties, the results from Ball (1) are used to derive the needed elasticities for use in the SWOPSIM framework.

Ball (1) examined the supply response of U.S. agriculture using the multiple-output profit function approach described above. He assumed that the unknown underlying restricted-profit function can be approximated by a second order Taylor series expansion of the translog function around the unit point. His profit function consisted of five aggregate outputs, six aggregate inputs, and a fixed factor of production. His output and input prices were constructed using the Tornqvist price index which is exact for aggregator functions that are homogeneous translog. Ball (1) tested and rejected the hypothesis that output prices are weakly separable, which means that a unique aggregate output price index does not exist. He also tested and rejected the hypothesis that the technology is nonjoint in inputs, which means that estimation using a single-output production or profit function is not valid.

Ball's estimated gross elasticities of supply and demand and profit shares are reproduced in table 1. Note that his elasticities fulfill the homogeneity condition; the sum of the elasticities in each row equals zero. Note also that the estimated elasticities fulfill the conditions of a "normal" technology; the outputs and inputs are gross complements and there are no regressive relationships.[4]

Ball's results are important because they provide an econometrically estimated, theoretically consistent set of elasticities, and information on the technology. However, his output elasticities are too aggregate to be used in SWOPSIM. In the next section, I will show how to disaggregate Ball's elasticities to conform with the output commodity set used in SWOPSIM.

Disaggregating Elasticities

In this section, I demonstrate the methodology used to disaggregate Ball's elasticities in order to conform to SWOPSIM's output set. The disaggregated elasticities are consistent with Ball's econometrically estimated aggregate elasticities; consequently, they are compatible with the assumption of profit maximization and multiple-output technology.

In order to maintain consistency with the data set used by Ball to estimate his elasticities, and to more closely adhere to agriculture as a single industry, I made several modifications to SWOPSIM's output set for the U.S. country model. One modification was to dairy products (butter, cheese, and powder) and oilseed products (meal and oil). These commodities were not included in the data set used by Ball to estimate his profit function. Furthermore, these products are generally not produced on the farm. At the farm level, the supply elasticity of these products with respect to input or output prices (except for the output price of milk or soybeans) is zero. These products were removed from the commodity set.[5]

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[4] It should be noted that the technology represented by the elasticities in table 1 is valid at the point of approximation.

[5] These products may be added later as a separate, process products, sector.

Table 1--Output supply, input demand elasticities, and profit shares

	Elasticity with respect to price of:											
Commodity	Live-stock	Fluid milk	Grains	Oil-seeds	Other crops	Durable equip-ment	Real estate	Farm-produced durables	Hired labor	Energy	Other purchased inputs	Row sum
					Coefficient							
Livestock	1.089	0.494	0.476	0.399	1.012	-0.534	-0.275	-0.369	-0.419	-0.286	-1.586	0.001
Fluid milk	1.266	.642	.604	.477	1.173	-.556	-.319	-.325	-.554	-.409	-1.998	.001
Grains	.991	.491	.838	.411	.947	-.192	-.425	-.470	-.307	-.166	-2.117	.001
Oilseeds	1.115	.502	.552	.432	1.023	-.519	-.342	-.409	-.358	-.321	-1.692	-.017
Other crops	1.091	.493	.491	.394	1.110	-.613	-.277	-.319	-.472	-.219	-1.681	-.002
Durable equipment	1.359	.552	.235	.473	1.446	-1.271	-.192	-.228	-.443	-.321	-1.611	-.001
Real estate	.864	.391	.641	.384	.806	-.237	-.584	-.622	-.252	-.206	-1.186	-.001
Farm produced durables	1.331	.457	.814	.528	1.066	-.323	-.713	-1.162	-.242	-.219	-1.537	0
Hired labor	1.625	.837	.571	.496	1.694	-.674	-.310	-.260	-1.500	-.379	-2.099	.001
Energy	1.467	.820	.409	.500	1.042	-.647	-.336	-.312	-.503	-.941	-1.588	-.089
Other purchased inputs	1.412	.694	.906	.538	1.388	-.564	-.336	-.379	-.483	-.276	-2.900	0
Profit share	1.8506	.7425	1.0378	.7742	1.8771	-.9008	-.7446	-.5133	-.5161	-.3896	-2.217	1.0008

Source: (1).

Another modification to the original SWOPSIM framework was the treatment of grain and livestock commodities, along with their interaction. The original SWOPSIM models treat grains as both an output and an input (which is useful for incorporating deficiency payments in policy analysis). The supply of livestock (for example, beef) depends on, among other factors, the price of corn. Since corn is treated as an input in the supply of beef, the price effect is negative. In addition, the demand for grains (for example, corn) depends not only on prices, but also on the supply of livestock commodities. The current version of SWOPSIM, therefore, contains feedbacks between grains as an output, their demand as input in the feed sector, and their subsequent effect on livestock production. Thus, SWOPSIM has a feed sector which is represented, in reduced form, by technical coefficients.

The data used by Ball to estimate his profit function were based on off-farm sales. Unlike the original SWOPSIM models, grains are only outputs in his system.[6] In this modification of SWOPSIM, the demand for grains (corn, for example) does not have a separate feed component; that is, the supply of livestock is not a variable in the corn demand equation. Any interactions between livestock and grain commodities in the modified version are due to technological interdependence (jointness).

Given the data definitions used by Ball and the use of his estimated elasticities to incorporate inputs, this version of SWOPSIM treats the feed-producing sector as a separate industry which is not modeled directly. Feed is treated similarly to other factors of production: demand is captured through the input side.[7]

The final modification was to add an aggregate output commodity (all other agricultural products) and six aggregate inputs from Ball's system to the SWOPSIM commodity set to close the system and assure homogeneity. These adjustments resulted in a model (INPUTS), which contains 22 commodities--16 outputs and 6 inputs.

The 22x22 elasticity matrix needed for the INPUTS model are disaggregated from the 11x11 input demand and output supply

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[6] It should be noted that the multiple-output profit function can include commodities that are both inputs and outputs. For those commodities, equations (2) and (3) are combined; if the result is positive, the commodity is a net output; if the result is negative, the commodity is a net input. The system estimated by Ball did not contain any such commodities.

[7] A more complete treatment of feeding relationships can be accomplished in one of two ways. One method is to disaggregate the input elasticity which includes feed (estimated by Ball) using the methodology described in the text for disaggregating the output elasticities. Alternatively, a separate feed-producing sector can be specified. Data and time constraints prevented the exploration of either approach.

elasticities calculated by Ball. The methodology used to obtain the disaggregate elasticities is adapted from Fuss (5).[8]

Fuss (5) was among the first to demonstrate, on the supply side, the feasibility of two-stage optimization based on the separability assumption. His objective was to estimate the demand for six types of energy in Canadian manufacturing. He specified a cost function which was weakly separable in capital, labor, materials, and the six types of energy. Because of data, multicollinearity, and other problems, he could not directly estimate this cost function. The assumption of weak separability, however, enabled him to aggregate his inputs and allowed him to use two-stage optimization to estimate the relationships while reducing multicollinearity problems.

As mentioned earlier, Ball's profit function is weakly separable in the five outputs and six inputs. Although the methodology is general and can be used to disaggregate outputs and inputs, I will focus on the output side. The five aggregate outputs from Ball and their 15 disaggregate components used in INPUTS are listed in table 2. Also listed in this table are the six aggregate factors of production. Given the commodity disaggregation, Ball's multiple-profit function can be represented as:

$$\pi(P,W;Z) = g[P_{lv}(P_{bf}, P_{pk}, P_{ml}, P_{pm}, P_{pe}), P_{dm}, P_{gr}(P_{wh}, P_{cn}, P_{cg}, P_{ri}), P_{os}(P_{sb}, P_{ob}), P_{oc}(P_{ct}, P_{tb}, P_{su}, P_{ot}), W_{de}, W_{re}, W_{fd}, W_{hl}, W_{en}, W_{oi}, Z], \qquad (12)$$

where P_{lv}, P_{gr}, P_{os}, P_{oc}, are the aggregator functions for the outputs, the W's are the input price indexes, and Z is the fixed factor of production. The mnemonics are given in table 2. The aggregator functions, in this case, can be defined as the unit revenue functions. As such, they exhibit the properties of revenue functions, including linear homogeneity.

According to Fuss, equation (12) can be estimated in two steps. The first step is to estimate the individual aggregator functions. These estimates provide the compensated supply functions and yield information on the substitution possibilities between commodities within the subfunction along the product transformation frontier while profit is held constant. These functions also provide information on the aggregate price index for the group which can be used as an instrumental variable in the estimation of equation (12) in the second stage. This two-stage procedure, therefore, provides information on gross supply response of the disaggregate commodities. For example, the supply of beef is given by:

$$\partial\pi/\partial P_{bf} = Y_{bf} = (\partial g/\partial P_{lv})(\partial P_{lv}/\partial P_{bf}), \qquad (13)$$

while the change in the supply of beef with respect to a change in the price of pork is given by:

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[8] See also (20).

$$\partial^2\pi/(\partial P_{bf}\partial P_{pk}) = \partial Y_{bf}/\partial P_{pk} = (\partial g/\partial P_{lv})(\partial^2 P_{lv}/\partial P_{bf}\partial P_{pk}) + (\partial^2 g/\partial P^2_{lv})(\partial P_{lv}/\partial P_{bf})(\partial P_{lv}/\partial P_{pk}). \quad (14)$$

Note that the total effect on beef supply from a change in the price of pork consists of two parts. One part is a movement along the product transformation frontier indicating the compensated substitution between beef and pork when all else is constant. This is the substitution effect and it is negative. The second part, the expansion effect, occurs because everything

Table 2--Disaggregation of Ball's commodity set for SWOPSIM

Ball	SWOPSIM
Commodity	
Livestock	Beef (BF)
	Pork (PK)
	Mutton and lamb (ML)
	Poultry eggs (PE)
	Poultry meat (PM)
Fluid milk	Dairy milk (DM)
Grains	Wheat (WH)
	Corn (CN)
	Other coarse grains (CG)
	Rice (RI)
Oilseeds	Soybeans (SB)
	Other seeds (OS)
Other crops	Cotton (CT)
	Sugar (SU)
	Tobacco (TB)
	Other crops (OC)
Real estate	Real estate (RE)
Durable equipment	Durable equipment (DE)
Farm-produced durables	Farm-produced durables (FD)
Hired labor	Hired labor (HL)
Energy	Energy (EN)
Other purchased inputs	Other purchased inputs (OI)

else is not held constant. The change in the price of pork changes the livestock aggregator which in turn affects substitution possibilities among all commodities. This effect is positive. In a "normal" technology, the expansion effect dominates the substitution effect.

The supply response of one commodity due to a change in the price of another commodity that is not in the same aggregator function can also be derived rather easily. For example, the change in the supply of beef due to a change in the price of wheat can be represented as:

$$\begin{aligned}\partial^2\pi/(\partial P_{bf}\partial P_{wh}) &= \partial Y_{bf}/\partial P_{wh} = (\partial g/\partial P_{lv})(\partial^2 P_{lv}/\partial P_{bf}\,\partial P_{wh}) + \\ &\quad (\partial^2 g/\partial P_{lv}\partial P_{gr})(\partial P_{lv}/\partial P_{bf})\ (\partial P_{gr}/\partial P_{wh}) \qquad (15)\\ &= (\partial^2 g/\partial P_{lv}\partial P_{gr})(\partial P_{lv}/\partial P_{bf})(\partial P_{gr}/\partial P_{wh}),\end{aligned}$$

because $(\partial^2 P_{lv}/\partial P_{bf}\partial P_{wh}) = 0$.

Equations (14) and (15) are easily converted into elasticity forms. For example, the elasticity form for equation (14) (commodities in same aggregator function) is:

$$E_{i,j} = E^{*}_{i,j} + S_j * E_n \qquad i,\ j,\ \epsilon\ n \qquad (16)$$

where,

$E_{i,j}$ = total elasticity of supply of commodity i with respect to change in price of commodity j,

$E^{*}_{i,j}$ = compensated elasticity of supply of commodity i,

S_j = revenue share of commodity j in aggregate group n,

E_n = the own-price elasticity of supply of aggregate commodity group n.

Similarly, the elasticity form of equation (15) (commodities in different aggregate groups) is:

$$E_{i,j} = S_j * E_{n,m} \qquad i \in n,\ j \in m,\quad n \cap m = \emptyset \qquad (17)$$

where,

S_j = revenue share of j in aggregate commodity group m,

$E_{n,m}$ = elasticity of supply (demand) of aggregate commodity n with respect to change in aggregate price m.

The compensated elasticity in equation (16) is obtained in the first step of the two step optimization; that is, estimation of the unit revenue function. The aggregate elasticity in equation (16) or (17) is obtained from the second step, the estimation of the profit function.

An alternative representation of equations (16) and (17) which makes the underlying production technology more transparent is:

$$E_{i,j} = S_j^n * \sigma_{i,j} + S_j^\pi * \sigma_n \qquad i,\ j,\ \epsilon\ n \qquad (16')$$

$$E_{i,j} = S_j^\pi * \sigma_{n,m} \qquad i\ \epsilon\ n,\quad j\ \epsilon\ m, \qquad (17')$$

where,

$E_{i,j}$ = as defined above,

S_j^π = profit share of commodity j,

S_j^n = revenue share of commodity j in aggregate group n,

σ_n = Allen elasticity of transformation for aggregate group n,

$\sigma_{i,j}$ = compensated Allen elasticity of transformation,

$\sigma_{n,m}$ = Allen elasticity of transformation (substitution) between aggregate group n and aggregate group m.

If estimates of unit revenue functions were available, the equations above could be used to generate the required elasticities. At this stage, however, the unit revenue functions have not been econometrically estimated. Equations (16), (17), (16'), or (17'), the aggregate elasticities from Ball (table 1), and various elasticities from SWOPSIM's U.S. country model are used in an iterative procedure to generate the 22x22 matrix of elasticities for the INPUTS version of SWOPSIM. These elasticities are given in table 3.[9]

Results in table 3 indicate that the disaggregate elasticities maintain the desirable properties discussed earlier. They are homogeneous of order zero, inputs are gross complements, and there are no regressive relationships.[10] The input elasticities have the right sign, output supply decreases when an input price increases, the demand for an input decreases when the price of an input increases, and the demand for an input increases when the price of an output increases. Furthermore, the relationship between gross (table 3) and compensated (appendix) elasticities (for elements that are on the diagonal) fulfill the conditions of a "normal" technology. That is, gross elasticities exceed (in absolute value) the value of the compensated elasticities (<u>9</u>).

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[9] The appendix contains the calculations used to derive the compensated Allen elasticities of transformation and the compensated supply elasticities. These elasticities, along with the aggregate elasticities from table 1, were used to derive the disaggregate elasticities presented in table 3.

[10] The reader is reminded that these properties hold at the point of approximation.

Table 3--Output supply and input demand elasticities derived from **multiple-output technology**

Commodity	Elasticity with respect to the price of:																						
	BF	PK	ML	PM	PE	DM	WH	CN	CG	RI	SB	OS	CT	SU	TB	OC	DE	RE	FD	HL	EN	OI	SUM
											Coefficient												
BF	0.90	-0.01	0	0.13	0.06	0.49	0.14	0.25	0.07	0.03	0.35	0.05	0.19	0.07	0.16	0.60	-0.53	-0.28	-0.37	-0.42	-0.29	-1.59	0
PK	-.02	1.00	.05	-.01	.07	.49	.14	.25	.07	.03	.35	.05	.19	.07	.16	.60	-.53	-.28	-.37	-.42	-.29	-1.59	0
ML	.09	1.17	.49	-.36	-.31	.49	.14	.25	.07	.03	.35	.05	.19	.07	.16	.60	-.53	-.28	-.37	-.42	-.29	-1.59	0
PM	.51	-.02	-.03	.65	-.02	.49	.14	.25	.07	.03	.35	.05	.19	.07	.16	.60	-.53	-.28	-.37	-.42	-.29	-1.59	0
PE	.41	.21	-.04	-.03	.55	.49	.14	.25	.07	.03	.35	.05	.19	.07	.16	.60	-.53	-.28	-.37	-.42	-.29	-1.59	0
DM	.66	.31	.01	.17	.10	.64	.17	.31	.08	.04	.41	.06	.22	.08	.18	.70	-.56	-.32	-.33	-.55	-.41	-2.00	0
WH	.52	.25	.01	.14	.08	.49	1.11	-.25	.05	.04	.36	.05	.17	.06	.15	.57	-.19	-.43	-.47	-.31	-.17	-2.12	0
CN	.52	.25	.01	.14	.08	.49	-.14	.95	-.01	.03	.36	.05	.17	.06	.15	.57	-.19	-.43	-.47	-.31	-.17	-2.12	0
CG	.52	.25	.01	.14	.08	.49	-.11	-.04	.96	.03	.36	.05	.17	.06	.15	.57	-.19	-.43	-.47	-.31	-.17	-2.12	0
RI	.52	.25	.01	.14	.08	.49	.19	.30	.07	.28	.36	.05	.17	.06	.15	.57	-.19	-.43	-.47	-.31	-.17	-2.12	0
SB	.58	.28	.01	.15	.09	.50	.16	.29	.08	.03	.60	-.17	.19	.07	.16	.61	-.52	-.34	-.41	-.36	-.32	-1.69	-.02
OS	.58	.28	.01	.15	.09	.50	.16	.29	.08	.03	-1.12	1.55	.19	.07	.16	.61	-.52	-.34	-.41	-.36	-.32	-1.69	-.02
CT	.57	.27	.01	.15	.09	.49	.14	.25	.07	.03	.34	.05	.74	-.01	.13	.24	-.61	-.28	-.32	-.47	-.22	-1.68	-.01
SU	.57	.27	.01	.15	.09	.49	.14	.25	.07	.03	.34	.05	-.02	.50	.13	.50	-.61	-.28	-.32	-.47	-.22	-1.68	0
TB	.57	.27	.01	.15	.09	.49	.14	.25	.07	.03	.34	.05	.16	.06	.25	.65	-.61	-.28	-.32	-.47	-.22	-1.68	0
OC	.57	.27	.01	.15	.09	.49	.14	.25	.07	.03	.34	.05	.07	.05	.17	.81	-.61	-.28	-.32	-.47	-.22	-1.68	0
DE	.71	.34	.01	.19	.11	.55	.07	.12	.03	.01	.41	.06	.27	.09	.22	.87	-1.27	-.19	-.23	-.44	-.32	-1.61	.01
RE	.45	.21	.01	.12	.07	.39	.18	.33	.09	.04	.33	.05	.15	.05	.12	.48	-.24	-.58	-.62	-.25	-.21	-1.19	-.01
FD	.70	.33	.01	.18	.11	.46	.23	.42	.11	.05	.46	.07	.20	.07	.16	.64	-.32	-.71	-1.16	-.24	-.22	-1.54	0
HL	.85	.40	.02	.22	.13	.84	.16	.30	.08	.03	.43	.06	.31	.11	.26	1.01	-.67	-.31	-.26	-1.50	-.38	-2.10	.01
EN	.77	.36	.02	.20	.12	.82	.12	.21	.06	.02	.43	.07	.19	.07	.16	.62	-.65	-.34	.31	-.50	-.94	-1.59	-.09
OI	.74	.35	.02	.19	.11	.69	.26	.47	.13	.05	.47	.07	.26	.09	.21	.83	-.56	-.34	-.38	-.48	-.28	-2.90	0

For commodity identification see table 2.
SUPSUM is the row sum.

Note that some of the gross cross-price elasticities between commodities in the same aggregate group are negative, indicating that the two commodities are substitutable in production. This is different from Ball's more aggregate results. The elasticities in table 3 do fulfill the requirements of the "normal" technology. The fact that some commodities have negative cross-price elasticities means that the compensated elasticity (the substitution effect) is larger than the expansion effect.

The elasticities in the original SWOPSIM U.S. country model are presented in table 4. The elasticities in table 4 are not from a homogeneous system, as reflected by the fact that row sums do not equal zero. If the price of all commodities changed, there would be no change in output supply or input demand given the system in table 3, whereas the system in table 4 would produce a net change in supply.

In comparing the elasticities in the two tables, we find the cross-price elasticities tend to be larger in table 3, indicating a more responsive production structure relative to the elasticities in table 4. Furthermore, table 4 contains many cross-price elasticities that are blank (or zero). The single-product nature of the model, represented by the elasticities in table 4, indicates that technological interdependence in production, for the most part, is assumed not to exist. This is illustrated by the relative lack of cross-price relationships between commodities from different aggregate groups.

Table 4 does contain nonzero elasticities for certain commodities that are not in the same aggregate group (for example, corn and beef). These elasticities are different from the elasticities in table 3, primarily due to the way feeding relationships were handled in the two systems. The elasticity of the supply of beef with respect to the price of corn is negative in table 4 indicating that corn is an input in the supply of beef, whereas this elasticity is positive in table 3 indicating the technological interdependence and the assumption of gross complimentarity associated with "normal" technology. As was stated earlier, the feeding relationships in the production structure reflected in table 3 are captured through the aggregate factor of production, other inputs (OI).

Many of the elasticities in tables 3 and 4, however, have the same value despite the different assumptions used to derive them. For example, 47 percent of the own-price elasticity of supply for the commodities which are common to the two models are equal. This result is not coincidental; rather, it is due to the procedure used to generate the elasticities in table 3, as explained in the appendix. This demonstrates that many of the elasticities in the current version of SWOPSIM's U.S. country model are consistent with the elasticities from the multiple-output profit function estimated by Ball. As demonstrated in the appendix, however, imposing the gross elasticity values from table 4 on the system represented in table 3 has implications on

Table 4--Output supply elasticities in present SWOPSIM

Commodity	BF	PK	ML	PM	PE	DM	DB	DC	DP	WH	CN	CG	RI	SB	SM	SO	OS	OM	OO	CT	SU	TB	SUM
	Elasticity with respect to the price of:																						
												Coefficient											
BF	0.65	-0.01	0	0	0	0.02				0	-0.09	-0.02			-0.01			0					0.53
PK	-.02	1.00	0	-.01	0	0				-.01	-.39	-.07			-.11			-.01					.37
ML	0	0	.80	0	0	0				0	-.27	-.05			0			0					.49
PM	0	-.01	0	.65	-.02	0				-.02	-.11	-.02			-.09			-.01					.37
PE	0	0	0	-.05	.55	0				-.02	-.19	-.03			-.06			-.01					.19
DM	.02	0	0	0	0	.50				0	-.06	-.01			-.01			0					.44
DB						-.20	0.50	-0.75	0.50														.05
DC						-.26	-.16	.64	-.16														.05
DP						-.31	.71	-1.07	.71														.05
WH										.60	-.25	-.06	0	0.05			-0.03			0	-0.01	0	.31
CN										-.11	.48	-.01	0	-.07			0			0	0	0	.29
CG										-.16	-.04	.60	0	-.09			-.05			0	0	0	.27
RI										0	0	0	.40	0			0			0	0	0	.40
SB										.05	-.15	-.03	0.	.60			0			-.11	0	-.01	.35
SM														-.38	.30	0.13							.05
SO														-.38	.30	.13							.05
OS										-.16	0	-.09	0	0			.55			.08	0	0	.21
OM																	-.69	.30	0.44				.05
OO																	-.69	.30	.44				.05
CT										0	0	0	0	-.25			-.03			.74	0	0	.46
SU										-.06	0	0	0	0			0			0	.50	0	.44
TB										0	0	0	0	-.05			0			0	0	.25	.20

DB= butter, DC= cheese, DP= milk powder, SM= soymeal, SO= soyoil, OM= other meals OO= other oils. The remaining commodities are identified in table 2. Empty spaces imply that the elasticity is zero. SUM is the row sum.

the value of the compensated and Allen elasticities and, thus, on the underlying production technology. Are these values a reasonable representation of technology? If not, the elasticity values in table 4 need to be further modified.

An Illustration of Model Results

In this section, results from three scenarios shocking the U.S. country model are presented. These scenarios are used to illustrate the effects of changing the production structure, as described above, on model results. The first scenario is an exogenous 10-percent increase in the producer price of beef. The second scenario is an exogenous 10-percent increase in the producer price of corn. The third scenario is a simultaneous 10-percent increase in the producer price of beef and corn. Many other scenarios could have been examined; however, these three were chosen because the two models differ most in their treatment of the grain-livestock interactions. Furthermore, the United States has different trade positions in the two commodities: importing beef and exporting corn.

A two-region SWOPSIM model was created to conduct the experiments: the United States and the rest of the world. One model contains the supply elasticities shown in table 3 (INPUTS) and the other model contains the supply elasticities shown in table 4 (CURRENT). The rest of the world (ROW) block is the same in both models as is consumer demand (except that the demand for grains in INPUTS does not depend on the supply of livestock). The factors of production in the INPUTS model are not traded, their supply is assumed to be infinitely elastic, and their prices are exogenous. Base data (prices, supply, demand, trade, etc.) for commodities that are included in both models are the same.

Scenario One: Beef Price Increase

The first experiment exogenously increased the producer price of beef in the United States by 10 percent. In the base year, the United States imported this commodity. The solution for each model, reported in table 5, is given as a percentage change from the base. Results from both models indicate that the exogenous increase in the producer price of beef has very little impact on the world price of the other traded commodities; the world price of commodities other than beef changes by less than 1 percent. Both models are also in relative agreement regarding the effect of the experiment on the world price of beef, with INPUTS indicating a 4-percent decrease, whereas CURRENT suggests almost a 5-percent decrease.

Both models are also in relative agreement regarding the impact of the experiment on agriculture in the United States. The equilibrium producer price of beef in both models is similar, with the INPUTS model indicating a slightly higher producer price than the CURRENT model. The results, however, diverge slightly regarding the impact of the experiment on the supply of the other commodities. The exogenous increase in the price of beef affects more commodities in the INPUTS model than in the CURRENT model as expected given the multiple-output technology of the INPUTS model. Thus, even though both models indicate a similar equilibrium beef producer price, the INPUTS model suggests a slightly smaller increase in the supply of beef and slightly larger impacts on the supply of other commodities (especially within the livestock group) relative to the CURRENT model. Despite an own-price elasticity of supply for beef that is larger in INPUTS, the cross-price elasticities (including inputs) tend to dampen the own-supply response. The CURRENT model, however, indicates larger supply responses to changes in the price of beef because of fewer cross-price terms which magnify the importance of own-price elasticity.

Despite the different elasticity structures of the two models, the equilibrium solution following the experiment is very similar. The relative agreement in the equilibrium solution of the two models is illustrated in table 6. This table reports the equilibrium producer price and output levels in the United States generated by INPUTS relative to CURRENT following the 10-percent increase in the producer price of beef. The results indicate that for most commodities, the equilibrium solution of the two models is within 1 percentage point of each other, and for some

Table 5--Percentage change from base due to a 10-percent increase in the producer price of beef in the United States

	Inputs model						Current model					
Commodity	World price	Producer price	Consumer price	Supply	Demand	Trade	World price	Producer price	Consumer price	Supply	Demand	Trade
						Percent						
BF	-4.19	4.91	1.81	2.23	-1.25	-54.37	-4.66	4.33	1.60	2.76	-1.12	-60.41
PK	.20	.31	.20	-1.84	.17	27.40	-.17	-.26	-.17	-.50	.45	13.23
ML	-.18	-.12	-.18	-1.20	.20	12.05	-.28	-.19	-.27	-.26	.13	3.40
PM	-.32	-.33	-.19	.16	.33	-4.66	-.19	-.20	-.11	-.17	.25	-12.28
PE	-.01	-.03	-.01	-.03	0	-2.41	.03	.07	.03	-.03	-.01	-1.09
DM	0	-2.57	-2.50	.58	.58	0	0	-.07	-.66	.03	.03	0
WH	-.46	-.35	-.53	.48	.04	.98	.07	.05	.07	-.06	.15	-.29
CN	-.63	-.60	-.63	.17	.09	.51	.36	.34	.36	.16	.36	-.74
CG	-.44	-.52	-.49	.25	0	1.45	.09	.11	.10	.04	.56	-2.50
RI	-.15	-.09	-.15	.38	.04	.60	0	-.01	-.01	0	0	-.01
SB	-.99	-1.21	-.99	.49	.42	.61	.05	.07	.05	-.01	-.01	-.01
OS	-.36	-.49	-.36	1.75	.12	17.86	0	.01	.01	-.01	0	-.10
CT	-.43	-.23	-.43	.60	.08	.84	0	.01	.01	-.01	0	.02
SU	-.29	-.14	-.06	.71	.01	-2.23	0	0	0	0	.01	.05
TB	-.33	-.30	-.33	.69	.07	29.88	0	0	0	0	0	-.13
DE	N/A	N/A	N/A	N/A	1.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RE	N/A	N/A	N/A	N/A	.35	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FD	N/A	N/A	N/A	N/A	1.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HL	N/A	N/A	N/A	N/A	.94	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EN	N/A	N/A	N/A	N/A	.73	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OI	N/A	N/A	N/A	N/A	.61	N/A	N/A	N/A	N/A	N/A	N/A	N/A

For commodity identification, see table 2.
N/A = not applicable.

commodities, the difference is less than 1 percent. The positive sign in table 6 indicates that equilibrium price (supply) is larger in the INPUTS model compared with the CURRENT model.

The advantage of the INPUTS model is that in addition to obtaining results which are very similar to the results from the CURRENT model, it also provides additional information on the demand for inputs. The exogenous 10-percent increase in the producer price of beef and the resulting changes in the supply of the other commodities results in an increase in the demand for inputs. Results in table 5 indicate that except for real estate, the demand for each input increases by about 1 percent. The results also suggest that beef production is relatively capital intensive since the demand for durable equipment and farm purchased durable equipment increase relatively more than the demand for the other inputs. The results also indicate that, as expected, beef production is not land intensive; the demand for land increases less than the demand for the other inputs.

Scenario Two: Corn Price Increase

The second scenario exogenously increased, by 10 percent, the U.S. producer price of corn, a commodity that the United States exports. Results from the two models are presented in table 7.

Table 6--Percentage change in the equilibrium producer price and supply INPUTS relative to CURRENT following a 10-percent increase in the producer price of beef in the United States

Commodity	Producer price	Supply
	Percent	
BF	0.56	-0.52
PK	.58	-1.35
ML	.07	-.94
PM	-.14	.33
PE	-.09	-.01
DM	-2.50	.55
WH	-.40	.55
CN	-.94	.01
CG	-.63	.21
RI	-.09	.38
SB	1.27	.51
OS	-.50	1.76
CT	-.24	.61
TB	-.14	.71
SU	-.30	.70

For commodity identification, see table 2.

Once again, the results from both models are relatively similar. The 10-percent increase in the corn price has almost a negligible impact on world prices of commodities other than corn, while causing the world corn price to decrease by about 7 percent.

With respect to the impacts on U.S. agriculture, both models indicate that the equilibrium producer price of corn, following the exogenous shock, is about 2 percent higher than the base price, and the resulting supply is about 1 percent higher than the base. Although the magnitudes are not large, the two models differ regarding the impact on other commodities, especially livestock, following the exogenous increase in the price of corn. The CURRENT model indicates that the price increase in corn results in a decrease in the supply of the livestock products. The INPUTS model indicates an opposite effect (except for the supply of pork and poultry). This result is not surprising given the different assumptions in the two models regarding grain-livestock interactions. As stated earlier, the price of corn enters the supply of livestock commodities as an input in the CURRENT model, whereas corn is only an output in the INPUTS model. The cross-price effects in INPUTS are based on the assumption of technological interdependence (jointness) and, for the most part, the effects are positive. Livestock supplies decrease in CURRENT following the exogenous increase in the price of corn because the higher corn price causes the cost of producing livestock to increase due to higher feeding costs.

Table 7--Percentage change from base due to a 10-percent increase in the producer price of corn in the United States

	Inputs model						Current model					
Commodity	World price	Producer price	Consumer price	Supply	Demand	Trade	World price	Producer price	Consumer price	Supply	Demand	Trade
	Percent											
BF	-0.14	-0.15	-0.06	0.06	0.03	-0.45	0.08	0.09	0.03	-0.14	-0.02	1.82
PK	-.17	-.26	-.17	-.04	.13	2.40	.08	.13	.08	-.74	-.06	9.18
ML	-.14	-.10	-.14	.04	.04	-.01	-.05	-.03	-.05	-.64	.06	6.07
PM	-.23	-.24	-.13	.02	.06	-1.11	-.04	-.04	-.02	-.26	.02	-8.51
PE	-.11	-.28	-.11	-.02	.04	-3.64	.03	.08	.03	-.38	-.01	-23.32
DM	0	-.21	-.20	.05	.05	0	.19	.19	.19	-.04	-.04	0
WH	.01	.01	.01	-.90	.28	-2.23	-.11	-.08	-.13	-.58	.30	-1.57
CN	-7.64	1.95	2.04	1.41	-.43	9.45	- 7.33	2.28	2.38	1.08	-.80	9.28
CG	-.14	-.17	-.16	-.67	.64	-7.00	-.30	-.35	-.33	-.31	.49	-4.15
RI	-.16	-.10	-.16	.11	.04	.15	-.01	-.01	-.01	0	0	-.01
SB	-.25	-.30	-.25	.05	.10	-.04	.18	.22	.18	-.20	-.10	-.35
OS	-.11	-.14	-.11	.32	.03	3.19	-.02	-.03	-.02	.03	0	.30
CT	-.08	-.05	-.08	0	.02	0	.02	.01	.02	-.05	0	-.06
SU	-.12	-.06	-.03	.01	.01	-.01	.03	.01	.01	.01	.07	.25
TB	-.01	-.01	-.01	.03	0	1.08	0	0	0	-.01	0	-.43
DE	N/A	N/A	N/A	N/A	-.31	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RE	N/A	N/A	N/A	N/A	.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FD	N/A	N/A	N/A	N/A	.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HL	N/A	N/A	N/A	N/A	-.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EN	N/A	N/A	N/A	N/A	-.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OI	N/A	N/A	N/A	N/A	.29	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A = not applicable.
For commodity identification, see table 2.

The additional information provided by INPUTS--the impact of the 10-percent increase in producer price of corn on the demand for inputs--is also shown in table 7. INPUTS indicates that the 10-percent increase in the producer price of corn has very little impact on the demand for inputs, reflecting the fact that output supply changed very little. In contrast to the previous scenario, the demand for inputs changed less than 1 percent following a 10-percent increase in the producer price of corn. The INPUTS model indicates that the demand for inputs is more responsive to a change in the price of beef relative to the same percentage change in the price of corn. This result is useful because it indicates that policies that affect different outputs have different implications on the demand for inputs. For example, the models indicate that a policy which exogenously increases the producer price of beef by 10 percent results in an increase in the demand for hired labor, whereas a policy which increases the producer price of corn by the same percentage results in a minor decrease in the demand for hired labor.

Scenario Three: Simultaneous Beef and Corn Price Increase

The third scenario simultaneously increased the producer price of beef and corn in the United States by 10 percent. The two models provided relatively similar results to the increase in the price of each commodity separately. This scenario is used to determine whether changes in more than one commodity will cause the solution generated by the two models to diverge.

Results from this simulation are presented in table 8. The two models differ somewhat on the implication of this scenario on world prices. The solution regarding the impact on the world price of beef is similar, but the two models differ on the implications of the experiment on the world price of the other commodities. For example, following the experiment, the world price of corn is 8 percent below the base in INPUTS and 7 percent below the base in CURRENT. The models also differ on the implications of the scenario on the world price of the other commodities. Although the results suggest relatively small changes in the world price of the other commodities, INPUTS suggests relatively larger adjustments compared with CURRENT. Furthermore, even though the magnitudes are small, the direction of change in world prices differs between the two models. INPUTS indicates that most of the world prices decrease due to the experiment, whereas CURRENT results indicate that some world prices increase while others decrease.

The impact of the scenario on U.S. agriculture, except for beef, also differs somewhat in the two models. Both models indicate that the impact of the simultaneous price increase results in raising the producer price of beef about 5 percent higher than the base. The results from the two models diverge regarding the implications of the scenario on other commodities, however, especially corn. For example, CURRENT suggests that the equilibrium producer price of corn is about 3 percent higher than the base, whereas INPUTS indicates that the producer price is only 1 percent higher than the base.

The impact on the demand for inputs as a result of the third experiment is also shown in table 8. The exogenous 10-percent increase in the price of beef and corn in the United States causes the demand for each input to increase by almost 1 percent. As expected, given the log-linear functional form, the percentage change in the demand for inputs is the sum of the percentage change of the individual experiments.

Conclusions

One of the major uses of SWOPSIM models is to analyze the impacts from trade liberalization using producer and consumer subsidy equivalent measures (PSE's and CSE's). Since the INPUTS model includes the demand for inputs, this model may be useful in determining the impacts of trade liberalization not only on output supply and demand, but also on the demand for inputs. The model can also be used to determine the impact of various policies on the demand for factors of production such as labor and capital in agriculture. For example, the two simple simulations indicated that a policy that increases the producer price of beef has different impacts on the demand for inputs than a policy that increases the producer price of corn. In addition, INPUTS can provide a more definitive assessment of the impact of trade liberalization on farm income.

Table 8--Percentage change from base due to a simultaneous 10-percent increase in the producer price of beef and corn in the United States

	Inputs model						Current model					
Commodity	World price	Producer Price	Consumer price	Supply	Demand	Trade	World price	Producer price	Consumer price	Supply	Demand	Trade
						Percent						
BF	-4.30	4.75	1.76	2.29	-1.22	-54.81	-4.58	4.43	1.63	2.62	-1.14	-58.58
PK	.03	.05	.03	-1.88	.29	29.79	-.09	-.14	-.09	-1.24	.38	22.39
ML	-.32	-.22	-.31	-1.15	.24	12.05	-.32	-.23	-.32	-.90	.19	9.45
PM	-.55	-.57	-.32	.18	.39	-5.78	-.23	-.24	-.13	-.44	.27	-20.78
PE	-.12	-.30	-.12	-.05	.04	-6.06	.06	.14	.06	-.40	-.02	-24.38
DM	0	-2.77	-2.69	.63	.63	0	0	.13	.12	-.01	-.01	0
WH	-.45	-.34	-.51	-.41	.32	-1.24	-.05	-.04	-.05	-.64	.45	-1.86
CN	-8.22	1.34	1.39	1.58	-.34	9.96	-7.00	2.62	2.74	1.24	-.44	8.54
CG	-.58	-.69	-.65	-.42	.64	-5.53	-.21	-.25	-.23	-.27	1.06	-6.61
RI	-.31	-.20	-.31	.49	.08	.75	-.02	-.01	-.02	-.01	0	-.01
SB	-1.24	-1.51	-1.24	.54	.52	.56	.24	.29	-.23	-.21	-.12	-.36
OS	-.47	-.63	-.47	2.08	.15	21.10	-.02	-.03	-.02	.01	-.01	.20
CT	-.51	-.28	-.51	.61	.10	.84	.03	.02	.03	-.06	-.01	-.08
SU	-.40	-.20	-.09	.72	.02	-2.23	.04	.02	.01	.01	.08	.30
TB	-.34	-.31	-.34	.72	.07	30.96	.01	.01	.01	-.01	0	-.56
DE	N/A	N/A	N/A	N/A	.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RE	N/A	N/A	N/A	N/A	.60	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FD	N/A	N/A	N/A	N/A	1.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HL	N/A	N/A	N/A	N/A	.84	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EN	N/A	N/A	N/A	N/A	.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OI	N/A	N/A	N/A	N/A	.90	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A = not applicable
For commodity identification, see table 2.

Since the methodology was applied only to the U.S. model, complete policy analysis was not undertaken. Further research is needed to extend the methodology to other country models so that SWOPSIM can provide a more complete policy analysis. Policymakers may need to incorporate implications of policy changes not only on outputs but also on inputs. At the very least, the EC, Canada, Australia, and Japan country models should be updated to include factors of production. This does not necessarily imply actual estimation of the complete set of elasticities. The methodology used in this report demonstrates how to employ existing estimates to derive the necessary elasticities.

The current data sets for the United States also need to be updated so that more direct statements regarding farm income can be made. In addition, the way PSE's are used in SWOPSIM may need to be modified so that input subsidies are explicitly incorporated into the modeling framework. How will trade liberalization scenarios change if input subsidies are not also reduced or eliminated? Further research is also needed in order to relax the assumption that the supply of each input is exogenous (that is, infinitely elastic). Will policy implications differ if input supply to agriculture is not perfectly elastic?

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Appendix

Given the methodology presented in the main text, the ideal way to generate the elasticities for use in the INPUTS model is to apply Fuss' methodology and econometrically estimate each unit revenue function in equation (12). At this time this has not been done. The approach used here is to employ the gross elasticities estimated by Ball and some of the elasticities contained in the present U.S. country model and iteratively calculate the remaining elasticities to use in the INPUTS model.

This appendix illustrates how the gross elasticities used in the U.S. country model of INPUTS were iteratively generated. A step-by-step presentation is provided for some of the commodities in the livestock aggregate, to give the reader a feel for how the disaggregate elasticities were calculated.[11] The 5x5 matrix of compensated price elasticities and the 5x5 matrix of Allen elasticities of transformation are given in appendix tables 1 and 2.

Step 1. Assume that the cross-price elasticities presently in CURRENT for beef with respect to pork (-0.01), pork with respect to poultry meat (-0.01), and poultry meat with respect to poultry eggs (-0.02), as well as the own-price elasticity of pork (1.0), and poultry meat (0.65), are correct.

Step 2. Use equation (16) to derive the compensated elasticities implied by the gross elasticities in step 1. These are reported in appendix table 1.

Step 3. The Allen elasticity of substitution is given by the expression: $\sigma_{ij} = E_{ij}/S_j$ (i,j = BF, PK, ML, PM, PE). This relationship is used with the compensated elasticities generated in step 2 to calculate the Allen elasticity of transformation for beef with respect to pork (-1.13), pork with respect to poultry meat (-1.16), and poultry meat with respect to poultry eggs (-1.34). Since the Allen elasticity of transformation matrix is symmetric, the three compensated price elasticities generate six Allen elasticities of transformation as shown in appendix table 2.

Step 4. Given the three Allen elasticities of transformation provided by symmetry, the relationship in step 3 is used to generate three compensated price elasticities; pork with respect to beef (-0.59), poultry meat with respect to pork (-0.29), and poultry eggs with respect to poultry meat (-0.18).

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[11] The approach taken in this analysis is based on holding the aggregate elasticities estimated by Ball constant. An alternative approach is to calculate the Allen elasticity of substitution implied by Ball's aggregate elasticities and use different shares to obtain a new set of aggregate elasticities which can then be used.

Appendix table 1--Compensated output supply elasticities for commodities in livestock products aggregate

Commodity	BF	PK	ML	PM	PE	SUM
	Elasticity with respect to the price of:					
			Coefficient			
BF	0.33	-0.28	-0.01	-0.02	0.03	0
PK	-.59	.73	.04	-.16	.02	0
ML	-.48	.90	.48	-.51	-.39	0
PM	-.07	-.29	-.04	.50	.11	0
PE	-.17	-.06	-.05	-.18	.46	0

For commodity identification, see table 2.

Appendix table 2--Allen elasticity of transformation, and product share for commodities in livestock products aggregate

Commodity	BF	PK	ML	PM	PE
			Coefficient		
BF	0.63	-1.13	-0.91	-0.12	-0.32
PK	-1.13	2.94	3.64	-1.16	-.25
ML	-.91	3.64	43.64	-3.73	-4.91
PM	-.12	-1.16	-3.73	3.66	-1.34
PE	-.32	-.25	-4.91	-1.34	5.79
Share	.524	.248	.011	.137	.080

For commodity identification, see table 2.

Step 5. Given the three compensated elasticities calculated in step 4, equation (16) or (16') is used to calculate the gross price elasticities used in INPUTS.

Step 6. Steps 1-5 generated three of the five elasticities in the pork and poultry meat supply equations. Using the fact that the compensated price elasticities are homogeneous, the remaining elasticities for these two commodities were assumed, thus providing compensated price elasticity for pork and poultry meat with respect to the price of the other two livestock commodities.

Step 7. Steps 2-6 were repeated to generate the remaining elasticities for the livestock group. If during the process a particular value generated elasticities which were not reasonable, a new elasticity value was used and the process repeated until the values were reasonable.

The steps outlined above were used to derive the compensated price and the Allen elasticity of transformation for commodities in the other aggregate groups (grains, oilseeds, and other crops). Those elasticities are presented in appendix tables 3-8.

The methodology described in this appendix generated disaggregated elasticities for products within aggregate commodity groups. These price elasticities are reported in table 3. The remaining elasticities in table 3, the cross-price elasticity for commodities in different aggregate groups, were generated using equation (17).

Appendix table 3--Compensated output supply elasticities for commodities in grain crops aggregate

Commodity	Elasticity with respect to the price of:				
	WH	CN	CG	RI	SUM
			Coefficient		
WH	0.87	-0.68	-0.17	-0.01	0
CN	-.38	.52	-.13	-.02	0
CG	-.35	-.47	.84	-.02	0
RI	-.05	-.13	-.05	.23	0

For commodity identification, see table 2.

Appendix table 4--Allen elasticity of transformation and product share for commodities in grain crops aggregate

Commodity	WH	CN	CG	RI
		Coefficient		
WH	3.05	-1.32	-1.23	-0.17
CN	-1.32	1.01	-.92	-.26
CG	-1.23	-.92	6.03	-.34
RI	-.17	-.26	-.34	3.98
Share	.285	.517	.140	.058

For commodity identification, see table 2.

Appendix table 5--Compensated output supply elasticities for commodities in other crops aggregate

Commodity	Elasticity with respect to the price of: CT	SU	TB	OC	SUM
			Coefficient		
CT	0.54	-0.08	-0.04	-0.42	0
SU	-.23	.43	-.04	-.16	0
TB	-.05	-.02	.08	-.02	0
OC	-.13	-.02	-.004	.15	0

For commodity identification, see table 2.

Appendix table 6--Allen elasticity of transformation and product share for commodities in other crops aggregate

Commodity	CT	SU	TB	OC
		Coefficient		
CT	2.91	-1.23	-0.26	-0.70
SU	-1.23	6.55	-.26	-.27
TB	-.26	-.26	.52	-.03
OC	-.70	-.27	-.03	.25
Share	.184	.065	.153	.597

For commodity identification, see table 2.

Appendix table 7--Compensated output supply elasticities for commodities in the oilseeds aggregate

Commodity	Elasticity with respect to the price of: SB	OS	SUM
		Coefficient	
SB	0.225	-0.225	0
OS	-1.49	1.49	0

For commodity identification, see table 2.

Appendix table 8--Allen elasticity of transformation and product share for commodities in the oilseeds aggregate

Commodity	SB	OS
	Coefficient	
SB	0.26	-1.72
OS	-1.72	11.37
Share	.869	.131

For commodity identification, see table 2.

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