Measuring the Effects of U.S. Meat Trade on Consumers' Welfare

Kuo S. Huang*

Abstract

A set of ordinary and inverse demand systems for U.S. quarterly meat consumption is estimated for use to measure the effects of U.S. meat trade on consumers' welfare. The approach is useful to incorporate all direct- and cross-commodity effects into price forecasting and the Hicksian compensating variation measurement.

Key words: compensating variation, ordinary and inverse demand systems

Agricultural trade reform has received much attention in the national and international forums, particularly since the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) negotiations in 1986. The participating nations agreed that some agricultural policies have distorted world trade, and they proposed to increase market access, reduce internal trade-distorting subsidies, and cut export subsidies. Agricultural trade reform would have profound effects on U.S. agriculture and on the producers and consumers of agricultural products. Since the effects of trade reform on producers have long been the issues in the policy debates, many studies like Vertrees focused on potential economic effects on U.S. farm exports and farmers' income but did not explore the effects on the welfare of consumers. To contribute to the methodology of assessing the impacts of foreign trade, this study measures the effects of U.S. meat trade on consumers' welfare.

The U.S. meat trade is characterized by increasing imports for manufacturing grade (grass fed) beef and pork, and increasing exports of high quality (grain fed) beef and broilers. The importance of foreign trade on U.S. meat consumption could be increased as trade reform progresses. Any reform measure would encourage the expansion of meat trade and immediately affect the amount of meat available in the domestic market. Given the interdependent demand relationships among various meats, the changes in the amount of some meats would cause the prices of all meats and thus consumers' welfare to change simultaneously. To adequately address this issue, this study proposes an inverse (price dependent) demand system approach to take into account the direct- and cross- commodity effects in the determination of meat prices. These projected multiple price changes are then used to measure the effects on consumers' welfare.

Marshall's concept of consumers' surplus, defined as the area under an uncompensated demand curve over a price change, has been widely used as a welfare measure to analyze agricultural policy such as in Tolley, et al. Deaton and Muellbauer (pp.185-186) argued, however, that the use of consumers' surplus as an analytical tool frequently seems to lead to errors and confusion. They proposed that taking the area under a compensated or Hicksian demand curve over a price change would be an appropriate welfare measure, because the Hicksian demand functions are the derivatives of

---

*Kuo S. Huang is an agricultural economist with the Economic Research Service, U.S. Department of Agriculture. The author thanks William F. Hahn for providing data and suggestions, and Journal reviewers for helpful comments.

J. Agr. and Applied Econ. 25 (July, 1993): 217-227

the cost function, and the integration of the demand functions gives the differences in costs of reaching the same indifference curve at two different price vectors. Willig, Shonkwiler, and Just, et al. had proposed some approximated Hicksian welfare measures to correct the Mashallian consumers' surplus. Furthermore, Hausman derived a measure of the Hicksian compensating variation from an indirect utility function which is retrieved from an observed market demand equation. These approaches, however, are useful for the welfare analysis with only a single price change. To improve the welfare measurement and reflect multiple price changes, this study develops an approximated Hicksian compensating variation measure with the required information of direct- and cross-compensated price elasticities obtained from an estimated ordinary (quantity dependent) demand system.

Measuring Procedure

The procedure discussed here can be used for general application to evaluating the effects of changes in quantities demanded on prices and consumers' welfare. At the beginning, an inverse demand system is formulated for use in price forecasts. It is followed by the procedure for measuring the Hicksian compensating variation incorporating the effects of multiple price changes.

Forecasting Prices

An inverse demand system, in which prices are functions of quantities demanded and income, can be used directly for forecasting prices. Let q denote an n-coordinate column vector of quantities demanded for a "representative" consumer, p an n-coordinate vector of the corresponding prices, $m = p'q$ the consumer's expenditure, and $u(q)$ the utility function, assumed non-decreasing and quasi-concave in q. The solution of maximizing the utility function subject to the expenditure constraint yields the Hotelling-Wold's identity or an inverse demand system in which the normalized price of ith commodity, say $r_i = p_i / m$, is a function of all quantities demanded:

$$(1) \quad r_i = u_i(q) / \textstyle\sum_j q_j u_j(q) \qquad i = 1, 2, \ldots, n$$

where $u_i(q)$ is the marginal utility of the ith commodity.

One also can use the concept of a distance function (or transformation function) to specify a compensated inverse demand system and its interdependent demand relationships. Following Deaton, a distance function, $d(u, q)$, on the utility u for a quantity vector q is defined as a scalar measure of the magnitude of the quantity vector proportional to the quantity vector which lies on the utility u, say q^u:

$$(2) \quad d(u, q) = q / q^u$$

Because the distance function and cost function are dual to one another, Deaton explored the properties of the distance function having almost the same properties as the cost function; that is, the distance function is increasing in q, decreasing in u (the only difference), homogeneous of degree one in q, and concave in q.

Deaton further derived a compensated inverse demand function for the ith commodity by differentiating the distance function with respect to q_i:

$$(3) \quad d_i(u, q) = (p_i / m)_u \qquad i = 1, 2, \ldots, n$$

This compensated inverse demand function is homogeneous of degree zero in q because of the linear homogeneity of the distance function. Also, from the concavity of a distance function, a Hessian matrix obtained as the second-order differential of $d(u, q)$ with respect to q, say $d_{ij}(u, q)$'s, is a symmetric and negative semidefinite matrix.

By incorporating the concept of a distance function, this study rewrites the quantity variable in the inverse demand equation (1) as $q = s\, q^*$, where the variable s is equivalent to a distance function, and q^* is a reference quantity vector on the base period utility curve. Thus, each inverse demand equation can be expressed as

$$(4) \quad r_i = g(s, q^*) \qquad i = 1, 2, \ldots, n$$

Since the functional form of this inverse demand system is unknown, one may approximate the demand system to a first-order differential form as

$$(5)\quad dr_i = \Sigma_j (\partial r_i / \partial q_j^*)\, dq_j^* + (\partial r_i / \partial s)\, ds \quad i = 1, 2, \ldots, n$$

By further expressing the price slopes of the above equation in terms of price flexibilities, an inverse demand system may be rewritten as

$$(6)\quad dr_i / r_i = \Sigma_j f_{ij}^* (dq_j^* / q_j^*) + g_i (ds / s) \quad i = 1, 2, \ldots, n$$

where $f_{ij}^* = (\partial r_i / \partial q_j^*)(q_j^* / r_i)$ is a compensated price flexibility of the *i*th commodity with respect to a quantity change of the *j*th commodity, and $g_i = (\partial r_i / \partial s)(s / r_i)$ is a scale flexibility showing the effect of the *i*th commodity price on the proportional change in all quantities demanded.

Similar to Huang (1988), one may estimate the inverse demand system (6) by incorporating the following parametric constraints of homogeneity, symmetry and scale aggregation restrictions: $\Sigma_j f_{ij}^* = 0$, $f_{ji}^* / w_i = f_{ij}^* / w_j$, and $\Sigma_i w_i g_i = -1$, where $w_i = p_i q_i / m$ is the expenditure weight of *i*th commodity. These parametric constraints obtained from Anderson are derivable from the properties of a distance function.

For empirical estimation, one may approximate the scale variable in (6) as the geometric expenditure-weighted average of individual quantity indexes: $\log s = \Sigma_j w_j \log q_j$ so that the derived uncompensated inverse demand system can be expressed solely in terms of actual quantity changes. As shown in Huang (1991), by substituting the linkage equation of compensated (f_{ij}^*) and uncompensated (f_{ij}) price flexibilities: $f_{ij}^* = f_{ij} - g_i w_j$, and applying the homogeneity condition: $\Sigma_j f_{ij}^* = 0$, the inverse demand system becomes

$$(7)\quad dr_i / r_i = \Sigma_j f_{ij} (dq_j / q_j) + g_i [ds / s - \Sigma_j w_j (dq_j / q_j)] \quad i = 1, 2, \ldots, n$$

The last term in square bracket disappears provided that the scale variable is defined as the geometric expenditure-weighted average of individual quantity indexes.

Calculating Consumers' Welfare

To provide a compensation scheme for the analysis of the impacts of multiple price changes on consumers' welfare, one may apply the Hicksian compensating variation (*CV*) measure as discussed below. The Hicksian compensating variation is defined as the minimum amount by which a consumer would have to be compensated after a price change in order to be as well off as before. In other words, let us consider a change in the price vector from p^0 to p^1 and the initial equilibrium utility level be u^0, the *CV* can be represented as the difference of expenditures between price changes as

$$(8)\quad CV = E(p^1, u^0) - E(p^0, u^0)$$

where the expenditure functions $E(p^1, u^0)$ and $E(p^0, u^0)$ are the minimum expenditures necessary to maintain the level of utility u^0 given prices p^1 and p^0. This welfare measure reflects additional expenditures being required to achieve the same level of utility as before the change in price. One may regard p^0 as the initial price level and p^1 as the price level after trade reform, and then compute the change in expenditures to represent the level of gain or loss in consumers' welfare. If the compensating variation is positive, the consumers' welfare is decreasing, or the other way around.

In equation (8), one can express $E(p^0, u^0) = p^{0\prime} q^0$ under the equilibrium in the initial period, and $E(p^1, u^0) = p^{1\prime} q^h(p^1, u^0)$, where $q^h(p^1, u^0)$ is the Hicksian compensated quantities demanded in response to a price p^1 in order to maintain the same initial utility u^0. Furthermore, if one defines the changes of prices and compensated quantities as $dp = p^1 - p^0$ and $dq^h = q^h - q^0$, the measurement of *CV* can be rewritten as

$$(9)\quad CV = p^{1\prime}\, dq^h + q^{0\prime}\, dp$$

Given the initial quantities demanded vector q^0, and the projected price vectors p^1 and dp from the inverse demand system, the key question for computing the compensating variation is to find a vector of changes in compensated quantities demanded dq^h. One can approximate the ith element of dq^h, say dq_i^h, by applying the first-order differential form as

$$(10)\quad dq_i^h = \Sigma_j\, (\partial q_i^h / \partial p_j)\, dp_j \qquad i = 1, 2, \ldots, n$$

$$(11)\quad dq_i^h / q_i = \Sigma_j\, e_{ij}^* \,(dp_j / p_j) \qquad i = 1, 2, \ldots, n$$

where $e_{ij}^* = (\partial q_i^h / \partial p_j)(p_j / q_i)$ is a compensated price elasticity of the ith commodity with respect to a price change of the jth commodity. Thus the change in compensated quantities demanded can be calculated on the basis of information about the compensated price elasticities and the price changes projected previously from the inverse demand system.

To provide information for the compensated price elasticities, one may follow Huang (1985) and estimate an ordinary demand system by using the first-order differential form similar to the inverse demand system as the following:

$$(12)\quad dq_i / q_i = \Sigma_j\, e_{ij}\,(dp_j / p_j) + \eta_i\,(dm / m) \qquad i = 1, 2, \ldots, n$$

where $e_{ij} = (\partial q_i / \partial p_j)(p_j / q_i)$ is a price elasticity of the ith commodity with respect to a price change of the jth commodity, and $\eta_i = (\partial q_i / \partial m)(m / q_i)$ is an expenditure elasticity of ith commodity. One can estimate this demand system by incorporating the following parametric constraints of homogeneity, symmetry, and Engel aggregation: $\Sigma_j\, e_{ij} = -\eta_i$, $e_{ji} / w_i + \eta_j = e_{ij} / w_j + \eta_i$, and $\Sigma_i\, w_i\, \eta_i = 1$, where $w_i = p_i\, q_i / m$ is the expenditure weight of ith commodity. Then, one can compute the compensated price elasticities by using the following identity:

$$(13)\quad e_{ij}^* = e_{ij} + w_j\, \eta_i \qquad i, j = 1, 2, \ldots, n$$

These compensated price elasticities are then used in computing the Hicksian compensating variation measure.

Empirical Results

Foreign Trade in U.S. Meat Consumption

A brief review about the role of foreign trade in U.S. meat consumption is given here to provide background information for the empirical analysis that follows. Major discussion will be based on table 1, in which the pattern of U.S. meat production, consumption, and trade is illustrated in 5-year averages of four consecutive periods over 1971-90.

The United States is the world's largest importer of beef, mainly manufacturing grade beef from Australia and New Zealand. The bulk of these imports are frozen boneless beef which are mixed with fatter trimmings from U.S. beef for use in hamburger and sausage products. U.S. meat import law places an upper limit on the amount of beef allowed into the country. When it appears that imports will exceed the "trigger" level, the U.S. Government negotiates "voluntary" restraint agreements with its major sources of beef. In addition to the meat import law, the United States charges a 2 cent per pound tariff on most imported beef items. Beef imports represented about 8 to 9 percent of U.S. beef consumption over 1971-90. Trade reform proposals might modify or eliminate the meat import law and lead to higher beef imports.

The United States is also a growing exporter of high quality beef. Beef exports increased from 0.5 percent of beef production in the 1970's to about 3 percent in the late 1980s. Japan is the most important beef customer, taking more than one half of all the U.S. exports. Through years of trade negotiations under the U.S.-Japan Beef and Citrus Agreement, Japan's beef import quotas were eliminated in April 1991. Then, the quotas were replaced by an import duty of 70 percent for one year and the duty rate will be lowered progressively over the next two years to 50 percent. The United States is seeking further tariff reductions during the current round of GATT multilateral trade talks. Japan's trade reform could increase beef imports and lead to higher exports of U.S. beef.

The United States was also the world's largest importer of pork during 1971-90, increasing

Table 1. U.S. Meat Production, Consumption, and Trade (yearly average)[a]

Period	1971-75	1976-80	1981-85	1986-90
		Million pounds		
Beef:				
Imports	1,811	2,156	1,910	2,262
Exports	120	137	276	765
Consumption	24,230	25,686	24,690	24,914
Production	22,541	23,716	23,099	23,471
Imports/consumption (percent)	7.50	8.45	7.73	9.09
Exports/production (percent)	0.54	0.59	1.19	3.28
Pork:				
Imports	499	491	788	1,049
Exports	247	288	207	178
Consumption	14,222	14,330	15,451	15,793
Production	13,952	14,279	14,984	15,057
Imports/consumption (percent)	3.53	3.44	5.10	6.67
Exports/production (percent)	1.82	2.05	1.37	1.17
Chicken:				
Exports	117	418	522	829
Consumption	8,567	10,377	12,695	16,037
Production	8,780	10,944	13,371	17,047
Exports/production (percent)	1.33	3.78	3.94	4.81

[a] Compiled from Putnam, J.J., and J.E. Allshouse. *Food Consumption, Prices, and Expenditures, 1968-89*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Stat. Bull. No.825, 1991.

more than double between 1971-75 and 1986-90 from 499 to 1,049 million pounds. In 1990, major sources of pork imports are 49 percent from Canada, 30 percent from Denmark, and 7 percent from Poland. The main U.S. policy instrument implemented for pork imports is tariffs on processed pork products. In particular, the United States used to impose a countervailing duties of about 8 Canadian cents per kilogram on imports of fresh, chilled, and frozen pork from Canada since August 1989. A U.S.-Canada panel ruling in June 1991, however, decided that the United States had to stop collecting duties on pork products from Canada and refund duties collected over the past two years; a separate duty is still in place on imports of live hogs. The ruling would imply an opening door to an increase of pork imports from Canada.

The United States is the world's major broiler exporter. Chicken (mainly broilers) meat exports rapidly increased from 117 to 829 million pounds with the shares to production increasing from 1.33 to 4.81 percent over 1971-90. The destinations of U.S. broiler exports varied over years; major importers in recent years were Japan, Hong Kong, Mexico, the Soviet Union, and Canada. Broiler consumption in these countries is continuing to rise, and the trade reform would force them to liberalize their broiler imports. The U.S. broiler exports could grow further because of the advantage of low feed grain costs and efficient production technology.

Estimated Demand Systems

The procedure developed previously for measuring the effects of foreign trade requires the estimation of an inverse demand system for forecasting meat prices and an ordinary demand system for providing compensated price elasticities in the measurement of consumers' welfare. Since these demand systems are, in general, not the inverse of one another in a statistical sense, direct estimation of each demand system is needed. Similar to Huang and Hahn, this study estimates both the demand systems for meats conditional on the allocation of meat expenditures for high quality beef, manufacturing grade beef, pork, and broilers. These meat products are differentiated by the foreign trade and industry in the United States, and thus the meat trade policy reforms would have different impacts on these meats. The meat demand systems defined in this study are implicitly assumed to be separable from the demands for all other goods, partly because of primary interest in these meat commodities and partly because of difficulty in obtaining the quarterly data series for other goods in consumers' budgeting.

The data used are quarterly disappearances of meat quantities and their retail prices covering the first quarter of 1970 to the fourth quarter of 1990. Per capita quarterly meat consumption data and their retail prices were taken from U.S. Department of Agriculture sources. In particular, the retail choice beef price was used as the price of high quality beef, and the hamburger price for the retail price of manufacturing grade beef. The data on the slaughter of cattle by classes was used to split beef production into high quality and manufacturing grade beefs. Grain fed animal slaughter determined high quality beef production. Grass fed cow and bull slaughter determined the production of manufacturing grade beef. Also, all U.S. imports were assumed to be manufacturing grade beef and all exports high quality beef.

The ordinary demand system expressed in equation (12) is estimated by the constrained maximum likelihood method, and the estimation results are reported in table 2. As shown in that table, the quarterly demand for high quality beef and pork is relatively elastic with direct-price elasticities of -0.78 and -0.67, while the elasticities for manufacturing grade beef and broilers are low, only -0.48 and -0.05. The estimated meat-expenditure elasticities for high quality beef and pork are rather high, 1.27 and 1.20, while the elasticities for manufacturing grade beef and broilers are not statistically significant.

To assess the performance of the model, the conventional R^2 and Durbin-Watson statistics are not applicable, because the variables are expressed in terms of first-order difference form. The measure of *RMS* (root-mean-square) errors expressed in percentage, however, is used to represent the goodness of fit for each equation. These errors are found to be within a 3 to 8 percent range. The constant term in each demand equation may reflect the potential time trends of demand for meats. Most estimated constants, except for broilers having a trend of increasing, are not statistically significant.

The estimates of the ordinary demand system are used to compute the compensated price elasticities contained in table 3. These price elasticities are then used as basic input information for computing the Hicksian compensating variation on the basis of equations (9) to (13). These compensated price elasticities imply that the high quality beef is substitutable for pork and broilers but complementary to manufacturing grade beef. The complementarily between two kinds of beef are not expected in consumption; the result is probably because manufacturing grade beef and grain fed beef are complements in the production of hamburger. Pork is substitutable for both kinds of beef, but complementary to broilers. In addition, manufacturing grade beef is complementary to broilers, but substitutable for pork.

To provide an instrumental model for forecasting quarterly meat prices, an inverse demand system for meats expressed in equation (6) is estimated by the constrained maximum likelihood method, and the results are reported in table 4. The estimated compensated direct-price flexibilities in the diagonal entries of the table appear to be smaller than expected. A comparison, however, with those obtained from the directly estimated uncompensated demand model (not shown here) without imposing parametric constraints shows the results are consistent and reasonable. Among the direct estimates, the uncompensated direct-price flexibilities are -0.6335 (high quality beef), -0.2323 (manufacturing grade beef), -0.5269 (pork), and -0.4187 (broilers). Finally, the goodness of fit of the demand system is satisfactory with the *RMS* errors less than 5 percent in each case. The small *RMS* errors ensure that the estimated inverse demand system is a reliable forecasting model for meat prices.

Simulated Price Changes and Consumers' Welfare

For the purpose of this paper, U.S. meat production is assumed to be relatively stable in the short run, and the immediate effects of more meat exports or imports would cause the availability of meats in the domestic market to decrease or

Table 2. Uncompensated Elasticities for Quarterly Meat Consumption[a]

Price	Beefh	Beefm	Pork	Broiler	Meat-exp	Constant	*RMS*
Quantity:							Percent
Beefh	-0.7794	-0.1708	-0.2677	-0.0478	1.2657	-0.0003	3.00
	(0.0986)	(0.0490)	(0.0765)	(0.0302)	(0.1173)	(0.0033)	
Beefm	-0.3453	-0.4814	0.7090	-0.0528	0.1705	0.0024	7.99
	(0.2793)	(0.2000)	(0.1926)	(0.1014)	(0.3063)	(0.0083)	
Pork	-0.4290	0.1320	-0.6719	-0.2364	1.2052	0.0044	5.47
	(0.1521)	(0.0583)	(0.1397)	(0.0486)	(0.2128)	(0.0058)	
Broiler	0.4598	-0.0224	-0.2822	-0.0522	-0.1030	0.0100	5.44
	(0.1700)	(0.0951)	(0.1453)	(0.0910)	(0.2134)	(0.0058)	
Weight	0.5054	0.0961	0.2943	0.1043			

[a] Figures in parentheses are the estimated standard errors. The abbreviated notations are Beefh (high quality beef), Beefm (manufacturing grade beef), Meat-exp (Meat expenditure), and *RMS* (root-mean-square error).

Table 3. Compensated Elasticities for Quarterly Meat Consumption[a]

Price	Beefh	Beefm	Pork	Broiler
Quantity:				
Beefh	-0.1398	-0.0493	0.1049	0.0841
Beefm	-0.2591	-0.4650	0.7592	-0.0350
Pork	0.1801	0.2478	-0.3171	-0.1107
Broiler	0.4078	-0.0323	-0.3126	-0.0630

[a]Computed from Table 2 on the basis of equation (13). The abbreviated notations are Beefh (high quality beef) and Beefm (manufacturing grade beef).

Table 4. Compensated Flexibilities for Quarterly Meat Consumption[a]

Quantity	Beefh	Beefm	Pork	Broiler	Scale	Constant	*RMS*
Price:							Percent
Beefh	-0.1606	-0.0431	0.1090	0.0948	-0.9140	0.0002	1.64
	(0.0307)	(0.0110)	(0.0186)	(0.0206)	(0.0685)	(0.0017)	
Beefm	-0.2270	-0.1630	0.3062	0.0838	-0.9032	-0.0012	3.98
	(0.0580)	(0.0391)	(0.0425)	(0.0436)	(0.1628)	(0.0042)	
Pork	0.1872	0.0999	-0.1838	-0.1033	-1.0222	0.0030	2.81
	(0.0319)	(0.0139)	(0.0335)	(0.0196)	(0.1100)	(0.0029)	
Broiler	0.4592	0.0772	-0.2916	-0.2449	-1.4435	0.0024	4.71
	(0.0999)	(0.0401)	(0.0553)	(0.0911)	(0.2273)	(0.0052)	
Weight	0.5054	0.0961	0.2943	0.1043			

[a] Figures in parentheses are the estimated standard errors. The abbreviated notations are Beefh (high quality beef), Beefm (manufacturing grade beef), and *RMS* error (root-mean-square error).

increase. The assumption is consistent with Vertrees, who argued that there would be little change in U.S. livestock policies to meet GATT commitments, and the U.S. livestock and poultry production by 1996 would be largely unchanged. Major effort in the following simulations is to quantify the amount of meat changes affecting meat prices and consumers' welfare.

According to the historical pattern of U.S. meat trades, some useful scenarios for simulation would be the increase of exports for high quality beef and broilers and imports for manufacturing grade beef and pork. Since the nature of reform for U.S. trade policies and those of other countries is unknown at this stage, it is difficult to have a precise estimation of possible changes in U.S. meat trades. This paper, however, is focused on the methodology issue to illustrate the potential effects of quarterly changes in meat prices and consumers' welfare from the baseline in the fourth quarter of 1990 by allowing for a one-percent change in the amount of each meat category or any possible combinations. These ranges of changes are illustrative, and do not represent any projection or opinion of the possible ranges of the effects of trade reform. The simulation results are summarized in table 5, in which savings in meat expenditures are used as a measure of welfare; these savings are shown in the column of the negative value of the compensating variation measures.

As shown in that table, a marginal one-percent decrease of high quality beef in scenario 1, due to more beef exports, for example, would cause all meat prices to increase and the economic well-being of consumers to decrease by spending \$0.57 more per person in quarterly meat expenditures. On the other hand, a marginal one-percent increase in the amount of manufacturing grade beef in scenario 2, due to more imports, for example, would substantially decrease the prices of both kinds of the beef and broilers, and the consumers' welfare would increase by a saving of \$0.11 per person in quarterly meat expenditures. The simulation results in scenario 3 reflect a marginal one-percent increase in pork quantity due to more pork imports. The prices of pork, broilers,

Table 5. Changes in Quarterly Meat Prices and Consumers' Welfare[a]

	A 1-percent change in amount of meats				Percent change in prices				
	Qbh	Qbm	Qpk	Qbr	Beefh	Beefm	Pork	Broiler	Per capita savings
							Percent		Dollars
(1)	-				0.622	0.683	0.329	0.270	-0.5680
(2)		+			-0.131	-0.250	0.002	-0.061	0.1086
(3)			+		-0.160	0.040	-0.485	-0.716	0.3501
(4)				-	0.001	0.010	0.210	0.395	-0.1297
(5)	-	+			0.492	0.434	0.331	0.209	-0.4596
(6)	-		+		0.462	0.724	-0.155	-0.446	-0.2174
(7)	-			-	0.623	0.964	0.539	0.666	-0.6979
(8)		+	+		-0.291	-0.209	-0.483	-0.778	0.4583
(9)		+		-	-0.130	-0.239	0.212	0.334	-0.0209
(10)			+	-	-0.159	0.051	-0.275	-0.321	0.2199
(11)	-	+	+		0.332	0.474	-0.154	-0.508	-0.1093
(12)	-	+		-	0.492	0.444	0.541	0.604	-0.5894
(13)	-		+	-	0.463	0.734	0.055	-0.051	-0.3479
(14)		+	+	-	-0.290	-0.199	-0.273	-0.383	0.3283
(15)	-	+	+	-	0.332	0.484	0.056	-0.112	-0.2396

[a] The signs + and - in each simulation represent increases and decreases by one percent of amount of a particular meat with abbreviated notations Qbh for high quality beef, Qbm for maunfacturing grade beef, Qpk for pork, and Qbr for broilers. Per capita savings are measured as the negative value of the compensating variation. Other abbreviated notations are Beefh (high quality beef) and Beefm (manufacturing grade beef).

and high quality beef would decrease substantially, and consumers' quarterly meat expenditures would save by $0.35 per person. In scenario 4, a marginal one-percent decrease in the amount of broilers due to more broiler exports would increase all meat prices, especially for broilers and pork, and the quarterly meat expenditures would slightly increase by $0.13 per person. Scenarios 5 to 15 are designated to reflect the mixed effects on meat prices and consumers' welfare under various combinations of changes in the amount of meats.

The simulation results contained in table 5 are as expected. An expansion of imports for manufacturing grade beef and pork would drop meat prices and increase the economic well-being of consumers, while opposite effects would occur in the increase of high quality beef and broiler exports. The changes in consumers' welfare in terms of amount of savings are much more sensitive in the categories of high quality beef and pork. This is in general consistent with their meat expenditure shares, in which the average shares in the sample period are about 50 percent spent on high quality beef, 29 percent on pork, and about 10 percent each on broilers and manufacturing grade beef. These simulated gains or losses could have significant impacts on aggregate consumers' welfare. For example, a one-percent increase in the availability of pork would save consumers about $0.35 or 0.31 percent of their quarterly meat budget, that is $114 in the baseline. Given the number of U.S. consumers--about 250 million persons--the quarterly savings would be $87.5 million for the nation.

Conclusion

In applied welfare analyses, it has been recognized that the use of the compensated demand curves leads to the appropriate welfare measures.

Most of the methods available for measuring the Hicksian compensating variation, however, are restricted for use with a single price change. Given the interdependent nature of demands in consumers' budgeting, such a welfare analysis is obviously not practical for empirical application. To accommodate for multiple price effects, this study approximates the compensating variation measure as a function of all price changes and compensated price elasticities, respectively, obtained from estimated inverse and ordinary demand systems. The unique feature of this approach is that all potential direct- and cross-commodity effects are incorporated into the price forecasting and the welfare measurement.

The developed procedure is applied to measure the effects of foreign trade on U.S. meat prices and consumers' welfare. Since no agreement has been reached in the GATT talks yet, it is difficult to define a scenario for simulation to reflect the precise nature of the trade reform of U.S. and foreign policies and the marketing structure of meats in the rest of world. The simulations conducted in this study, however, demonstrate the usefulness of the methodology in measuring the effects of foreign trade under any combination of meat quantity changes tailored to specific trade policy analyses. The significance of measuring these foreign trade effects is growing because there is a trend of increasing U.S. exports for high quality beef and broilers and imports for pork and manufacturing grade beef. Finally, since the model specified in this study is focused on consumers' behavior but does not explicitly recognize the supply side of the meat markets, an extension of this research to a general demand-supply equilibrium model would make the empirical results more practical and useful.

References

Anderson, R.W. "Some Theory of Inverse Demand for Applied Demand Analysis." *Eur. Econ. Rev.* 14(1980):281-290.

Deaton, A.J. "The Distance Function in Consumer Behaviour with Application to Index Numbers and Optimal Taxation." *Rev. Econ. Stud.* 46(1979):391-405.

Deaton, A.J., and J. Muellbauer. *Economics and Consumer Behavior.* Cambridge, U. K.: Cambridge University Press, 1980.

Hausman, J.A. "Exact Consumer's Surplus and Deadweight Loss." *Amer. Econ. Rev.* 71(1981):662-676.

Huang, K.S. *U.S. Demand for Food: A Complete System of Price and Income Effects.* Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Tech. Bull. No.1714, 1985.

Huang, K.S. "An Inverse Demand System for U.S. Composite Foods." *Amer. J. Agr. Econ.* 70(1988):902-909.

Huang, K.S. *U.S. Demand for Food: A Complete System of Quantity Effects on Prices.* Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Tech. Bull. No.1795, 1991.

Huang, K.S., and W.F. Hahn. "Foreign Trade Implication for U.S. Demand for Beef." USDA S-216 Regional Committee's Symposium on Policy Implications for U.S. Agriculture of Changes in Demand for Food, Washington D.C., 1991.

Just, R.E., D.L. Hueth, and A. Schmitz. *Applied Welfare Economics and Public Policy.* Englewood Cliffs, NJ: Prentice-Hall, 1982.

Putnam, J.J., and J.E. Allshouse. *Food Consumption, Prices, and Expenditures, 1968-89*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Stat. Bull. No.825, 1991.

Shonkwiler, J.S. "Consumer's Surplus Revisited." *Amer. J. Agr. Econ.* 73(1991):410-414.

Tolley, G.S., V. Thomas and C.H. Wong. *Agricultural Price Policies and the Developing Countries.* Baltimore: John Hopkins University Press, 1982.

Vertrees J. *Economic Implications of the Uruguay Round for U.S. Agriculture.* Washington DC: U.S. Department of Agriculture, Economic Analysis Staff, Office of Economics, 1991.

Willig, R.D. "Consumer's Surplus Without Apology." *Amer. Econ. Rev.* 66(1976):589-597.