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A Look at Food Price Elasticities and Flexibilities

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Can Inverted Price Elasticities Be Used as Price Flexibilities?

Food price elasticities, defined as the percentage of changes in quantities demand for foods corresponding to given changes in food prices, and food price flexibilities defined reversely, are widely used in agricultural policy and program analyses. Agricultural economists often use flexibility measures for making agricultural pricing decisions to reflect that quantities and income are given in farm market demand relationships with price adjustments providing the market-clearing mechanism. Because of limited empirical flexibility estimates, most agricultural economists take the reciprocal of a directly estimated elasticity, or more rigorously the inversion of an elasticity matrix as flexibility measures. How reliable is it to obtain price flexibilities from inverting price elasticities?

Theoretically, Price Flexibilities Are the Inverse of Elasticities

The Marshallian demands have two purposes: one is to show the amounts consumers will buy at given prices, and the other is to show the prices consumers will pay at given quantities. The price into a quantity-dependent function defines an ordinary demand model in which the quantity demanded of a commodity is a function of all prices and income. The quantity into a price-dependent function defines an inverse demand model in which the price of a commodity is a function of all quantities demanded and income.

Let $\boldsymbol{q}$ denote a vector of n quantities demanded for a representative consumer, $\boldsymbol{p}$ a vector of prices, $\boldsymbol{r} = \boldsymbol{p} / m$ a vector of the normalized prices, $m = \boldsymbol{p}'\boldsymbol{q}$ the consumer's income (or

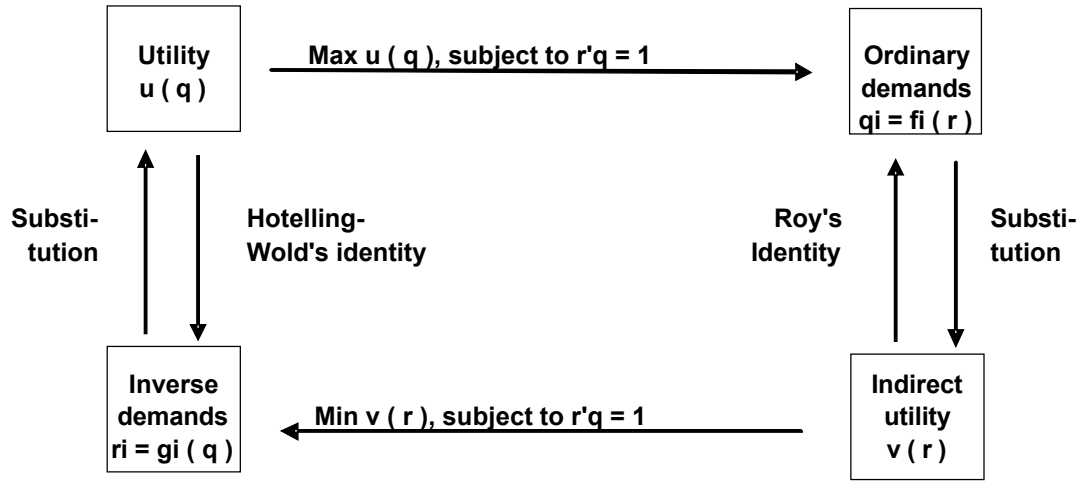
expenditure), and $u(\boldsymbol{q})$ the utility function. The primal function for maximizing consumer utility gives ordinary demands as $q_i = f_i(\boldsymbol{r})$.

To derive an inverse demand system, one can use dual relationships by substituting the equilibrium quantity q_i into the utility function, yielding an indirect utility function, say $v(\boldsymbol{r})$, which gives the maximized utility for specified values of the normalized prices. The primal function for minimizing indirect utility gives inverse demands as $r_i = g_i(\boldsymbol{q})$.

Alternatively, the Hotelling-Wold identity can be used to derive an inverse demand system from a utility function as $r_i = u_i(\boldsymbol{q}) / \Sigma_j\, q_j\, u_j(\boldsymbol{q})$. The Roy identity can be used to derive an ordinary demand system from an indirect utility function as $q_i = -[\partial v(\boldsymbol{p}, m)/\partial p_i]/[\partial v(\boldsymbol{p}, m)/\partial m]$.

The above dual properties are summarized in figure with an arrow indicating the direction of transformation. Now it becomes apparent from the figure that both the inverse demand system and the ordinary demand system are consistent with the same classical framework of consumer utility maximization. Therefore, the matrices of food price elasticities and flexibilities derived from these demand systems are theoretical consistent and reciprocal with each other.

Figure—The duality relationships of Marshallian demands



But Statistically, Price Flexibilities Are Not the Inverse of Elasticities

The matrices of elasticities and flexibilities, however, are in general not the inverse of one another in a statistical sense. For illustration, let's consider a set of single demand equations: $q = a\,p + u$ and $p = b\,q + v$, where q and p are the relative changes of quantity and price of a commodity, and parameters a and b are price elasticity and flexibility, respectively, and u and v are stochastic disturbance terms. For an economic model without the stochastic disturbance terms, there is no doubt that the price flexibility b is always a reciprocal to the price elasticity a. But for a statistical model with the stochastic disturbance terms, the estimates by applying the commonly used ordinary least squares give $a^* = (\boldsymbol{p}'\boldsymbol{q}) / (\boldsymbol{p}'\boldsymbol{p})$, and $b^* = (\boldsymbol{p}'\boldsymbol{q}) / (\boldsymbol{q}'\boldsymbol{q})$, where $\boldsymbol{p}$ and $\boldsymbol{q}$ are two-column vectors of price and quantity observations. According to the Cauchy-Schwarz inequality, for any vectors $\boldsymbol{p}$, $\boldsymbol{q}$ of real elements, $(\boldsymbol{p}'\boldsymbol{q})^2 \leq (\boldsymbol{p}'\boldsymbol{p})\,(\boldsymbol{q}'\boldsymbol{q})$. Therefore, the following inequality should hold for the estimates: $a^*\,b^* \leq 1$. In other words, even though a simple form of demand equation, one cannot anticipate that the estimated price elasticity and its corresponding price flexibility should be reciprocals of each other.

For a general demand system with discernible cross-commodity effects, the estimated price

flexibilities are certainly not the inverse of the estimated price elasticities. Why? First, for any well-known estimation procedure, the sum of residuals is minimized along the quantity axis in the estimation of an ordinary demand system, whereas the sum of residuals is minimized along the price axis in the estimation of an inverse demand system. Second, by inverting a price elasticity matrix, one ignores the stochastic nature of the statistical estimates and treats the point estimates of the demand parameters as exact numbers. Third, the inverted results are quite sensitive to the numerical structure of a demand matrix being inverted, and that could cause unstable results.

The estimates of two U.S. food demand systems for 39 food categories and 1 nonfood sector are shown in table for comparing the difference between the estimated price flexibilities and those inverted price flexibilities. In the table, the estimates of direct-price elasticities and flexibilities are listed in column A and C, and the inverted direct-price flexibilities listed in column B. As anticipated, the inverted price flexibilities are substantially different from those of the estimated price flexibilities. The ratios of inverted direct-price flexibilities to those estimated directly are listed in the last column of the table. For most food categories, the ratios in absolute value are larger than 1 implying that the inverted price flexibilities are substantially different from those estimated directly.

Directly Estimated Price Flexibilities Are More Accurate

Although the matrices of elasticities and flexibilities are in deed reciprocal to each other in an economic model, the two matrices are in general not the inverse of one another in a statistical sense. It is not proper to use the inverted elasticity as flexibility measures in agricultural policy and program analyses because of sizable measurement errors and inadequate interpretation of demand responses. The flexibilities from a directly estimated inverse demand system should be used to assess the price effects of quantity changes. To evaluate quantity effects of price changes, however, only elasticities from a directly estimated ordinary

demand system should be used.

Table 1--Comparison of directly estimated and inverted price flexibilities

Food Category	Estimated direct-price elasticity	Inverted direct-price flexibility	Estimated direct-price flexibility	Ratio of difference
	(A)	(B)	(C)	(B)/(C)
Beef	-0.621	-1.907	-1.156	1.65
Pork	-0.728	-1.396	-1.142	1.22
Other meats	-1.874	0.224	-0.198	-1.13
Chicken	-0.372	-1.783	-1.239	1.44
Turkey	-0.535	-1.526	-0.594	2.57
Fresh and frozen fish	0.121	0.910	-0.157	-5.80
Canned and cured fish	-0.372	-1.722	-0.036	48.38
Eggs	-0.110	-5.705	-3.689	1.55
Cheese	-0.247	-1.649	-0.366	4.51
Fluid milk	-0.043	-0.436	-0.294	1.48
Evaporated and dry milk	-0.276	-1.650	-0.095	17.35
Wheat flour	-0.078	-11.041	-0.313	35.32
Rice	0.066	6.573	-0.236	-27.87
Potatoes	-0.098	2.619	-0.711	-3.69
Butter	-0.243	0.467	-0.502	-0.93
Margarine	-0.009	4.477	-0.130	-34.49
Other fats and oils	-0.139	-1.344	-0.647	2.08
Apples	-0.190	3.285	-0.413	-7.95
Oranges	-0.849	-2.036	-0.756	2.69
Bananas	-0.499	-0.966	-0.335	2.89
Grapes	-1.180	0.316	-0.419	-0.75
Grapefruits	-0.455	-6.629	-0.637	10.41
Other fresh fruits	-0.416	-1.048	-0.083	12.66

Lettuce	-0.090	-1.140	-0.774	1.47
Tomatoes	-0.622	-2.477	-0.719	3.45
Celery	-0.078	-3.709	-0.687	5.40
Onions	-0.207	-5.705	-1.367	4.17
Carrots	-0.534	-3.262	-0.101	32.30
Other fresh vegetables	-0.215	0.820	-0.177	-4.64
Fruit juices	-0.558	-2.035	-0.781	2.61
Canned tomatoes	-0.169	0.602	-0.360	-1.67
Canned peas	-0.534	-0.463	-0.228	2.03
Canned fruit cocktail	-0.740	-0.678	-0.115	5.92
Peanuts and tree nuts	-0.169	5.788	-0.263	-22.02
Other processed F&V	-0.151	-1.666	-0.493	3.38
Sugar	-0.037	0.335	-2.480	-0.14
Sweeteners	-0.052	1.823	-0.155	-11.73
Coffee and tea	-0.176	-0.973	-2.515	0.39
Frozen dairy products	-0.078	3.278	-0.196	-16.71
Nonfood	-0.980	-0.890	-0.902	0.99