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Retail-Farm Price Margins and Consumer Product Diversity

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Abstract

This bulletin provides an alternative approach for computing retail-farm price margins. Current published estimates of retail-farm price margins are calculated assuming that food markets are comprised of identical firms producing, in fixed-factor proportions, a homogeneous set of final food products. The approach presented here relaxes these assumptions by relying on an expenditure-based measure, justified by the Generalized Composite Commodity Theorem, that reflects consumer demand for the many different elementary food products associated with a modern food market. This measure allows a direct link between consumer demand for diverse elementary products and food quality and marketing services where increases in retail-farm price margins, for example, can be traced to increases in consumer purchases of high-value products. Retail-farm price margins based on the alternative approach are estimated here for seven major U.S. food markets for each year from 1980-97. Although the alternative retail-farm price margins and the currently published estimates show similar trends, they also show significant differences, particularly in more recent years, that can be traced to shifts in increased consumer demand for marketing services.

Keywords: Retail-farm price margins, marketing services, food quality, consumer demand, Generalized Composite Commodity Theorem.

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Summary

For decades, economists have attempted to explain the decline of the share of the U.S. consumer food dollar allocated to farmers. A factor contributing to this decline is the increase in consumer demand for off-farm or marketing services for food. Declining farm shares are often reflected in rising retail-farm price margins. USDA's Economic Research Service (ERS) publishes estimates of retail-farm price margins. However, at the heart of these estimates is the assumption that a food market is comprised of identical firms producing, in fixed-factor proportions, a homogeneous set of final food products. While periodically adjusted to reflect diversity, these adjustments may lead to biased estimates of retail-farm price margins that can be interpreted as evidence of market power.

The key to the computation of the new estimates presented in this study is the evaluation of a single, market-level measure of composite consumer demand. We appeal to an expenditure-based measure, justified by the Generalized Composite Commodity Theorem, that can consistently reflect consumer demand for the many different elementary food products associated with a modern food market. This measure allows a direct link between consumer demand for diverse elementary products and food quality or, equivalently, marketing services. This is important because a competitive retail-farm price margin is the price that consumers are willing to pay for marketing services.

Annual data from 1980-97 for seven major U.S. food markets support the new estimates. Scatter plots of output and price ratios suggest diminishing returns or input substitution at the market level in the pork, poultry, egg, dairy, fresh fruit and fresh vegetable markets, and technological change in the beef market. Evidence of diminishing returns at the market level supports the new estimates, as input substitution arises from both the diversity of technologies among firms and the diversity of final food products. Evidence of technical change also supports the new estimates since technical change is automatically incorporated into variable input-output ratios associated with the new estimates. The annual data indicate that both the current and new estimates follow similar trends, but that they respond differently to changing market conditions. In particular, we find that changes in the new estimates appear to be more 'in phase' with changes in food quality than the current estimates.

We trace differences in the estimates to differences in consumer demand for the diverse elementary products. For example, systematic increases in retail-farm price margins for beef can be traced to systematic increases in consumer purchases of high-valued steak and a relatively constant demand for low-valued ground beef. Such differences in demand suggest that consumers have at least some choice over food quality and as such, over retail-farm price margins.

Introduction

For decades economists have attempted to explain the decline of the share of the U.S. consumer food dollar allocated to farmers. A factor contributing to this decline is the increase in consumer demand for off-farm or marketing services for food. That is, as consumers demand more marketing services in the form of greater convenience or processing, the farm value share declines. Historically, a number of researchers have documented the importance of the demand for marketing services. For example, Bunkers and Cochrane (1957) and Waldorf (1966) find that increases in the demand for marketing services for all food account for a large share of the decline in the farm value share.

Declining farm shares are often reflected in rising retail-farm price margins. USDA's Economic Research Service (ERS) publishes estimates of retail-farm price margins based on fixed farm proportions.[1] These estimates cannot link consumers' increased demand for marketing services (Kinsey and Senauer, 1996) to retail-to-farm price margins that rise faster than retail food prices. While ERS periodically updates its fixed weights and makes other adjustments to reflect changes in the "quality" of consumer food products, these changes lag actual changes in quality and may lead to serious biases in true retail-farm price margins.[2]

In this study, we compare USDA's current estimates with efficiency-based measures of retail-farm price margins that pertain to markets with diverse firms and diverse food products.

Conceptually, different products represent different bundles of farm and marketing services, and the new estimates computed below represent the value of marketing services associated with a composite market's mix of products. The new estimates can be used to show that growing consumer demand for marketing-service-intensive products translates into declining farm shares and rising retail-farm price spreads.

The rising spreads and declining farm shares that have been observed over the past decade have often been attributable to imperfectly competitive food markets. However, our estimates illustrate that such patterns are also consistent with a competitive industry characterized by diversity. The procedures presented below should not only yield more accurate estimates of price margins but should also allow the computation of these values more directly and effortlessly.

[1]In particular, ERS publishes two related estimates of price spreads. First, price spreads computed for individual categories of the market basket are based on fixed farm product equivalent ratios and estimates of average annual quantities of food purchased per household in a given base period (currently 1982-84). Second, price spreads computed for selected individual groups of food products (beef and pork) are simply the difference between a retail price and a retail-equivalent farm value assuming a fixed farm product equivalent ratio.

[2]This problem is analogous to the issue of whether consumer price index numbers, which are based on fixed quantities, accurately reflect changes in the true cost of living of consumers.

Methodology

In this study we compare two sets of estimates of retail-farm price margins. Both define retail-farm price margins as the difference between a market's average retail-price and its retail-equivalent farm price, and both have been justified on efficiency grounds (Reed and Clark 1997).

The first set is the current ERS estimates. The current estimates are based on fixed-factor proportions at the market level. In particular, if P_r and P_f denote a market's average retail and farm price and θ denotes a fixed farm-input–food-output coefficient, an estimate of a price spread for that particular market can be represented as

$$S = P_r - \theta P_f. \qquad (1)$$

Corresponding to equation 1 is a definition of the farm value share. Note that according to equation 1 the spread-to-retail price ratio $S / P_r = [1 - K]$ where the farm share, K, is $\theta (P_f / P_r)$. Hence implicit in the current estimates is a farm share that does not reflect changes in consumer demand for marketing services in the products that they purchase.[3]

The second set of estimates, denoted here as the new estimates, relax the restriction of a fixed input-output coefficient. If Q denotes composite consumer demand for a particular industry's output and F denotes the industry's demand for farm inputs, the new estimate is

$$M = P_r - (F/Q) P_f. \qquad (2)$$

Equation 2 implies $M/P_r = [1 - K]$ where the farm share, K, is defined naturally as $(P_f F_f / P_r Q)$. Implicit in the new estimates is a farm share that directly reflects changes in consumer demand for marketing services in the products that they purchase.

Fixing the farm-to-output ratio leads to problems in evaluating equation 1. For markets like beef or pork, the farm input is generally considered to be a fairly homogeneous commodity. In these markets, the problem lies in choosing a particular elementary retail product price that represents the average industry price P_r. By choosing a particular per unit product price (instead of an average price index) one implicitly restricts the array of final consumer products associated with a market to be identical. For other markets, like fresh fruits and vegetables, in which the farm commodity is heterogeneous, the problem becomes one of defining an average per unit farm price.

More generally, the problem with fixing a market's input-output ratio to a parameter, θ, is that it restricts the description of diversity. In particular, for a given fixed industry technology (no technological change) a fixed θ implies that when relative input prices change, the marginal cost of each fixed-proportions-producing firm shifts in the same way as every other firm in the industry. This means, for example, that if energy prices rise relative to farm prices, each identical firm utilizes inputs in the same fixed proportion and makes the same relative contribution to industry supply as it did before the price change.

On the other hand, the input-output ratio F/Q in equation 2 automatically allows for both technological change and differential supply responses among firms with different technologies. In particular, (F/Q) can automatically account for the effect of technological change at the firm or plant level that leads to the utilization of inputs in different proportions. The production process might be altered, for example, with improvements in plant production. However, if technology is fixed (which is the usual case) but varies across the firms of an industry, changes in relative factor prices will alter F/Q (Wohlgenant, 1989; Wohlgenant and Haidacher, 1989).

To see this, suppose again that energy prices rise relative to farm prices, and that the firms in an industry produce an identical product, but are bestowed with different technologies.[4] In this case, the marginal costs of firms with energy-intensive technologies will rise more than the marginal costs of firms with farm-intensive technologies. This means that after the relative increase in the energy price, energy-intensive firms contribute proportionately less and farm-intensive firms contribute proportionately more, to industry output. At the industry level then, F/Q rises. Hence, even if each firm produces the same product in fixed pro-

[3]It is important to note that while equation 1 forms the basis of the ERS estimates, ERS adjusts this basic formula when publishing its estimates. For example, for some markets ERS (infrequently) revises its estimates of θ. Furthermore, the basic estimates are updated based on current information on consumer expenditures.

[4]These technologies can be characterized as fixed-proportions technologies as long as the input-output coefficients vary across firms.

portions, input substitution occurs through the allocation of different production technologies across the industry. Note that in response to the increase in relative energy prices, equation 2 suggests that the increase in F/Q dampens the increase in retail-farm price margins.

One way to detect input substitution is to find empirical evidence of *diminishing returns* to the farm input. In this case, diminishing returns implies that with all factors held constant except the farm factor, the marginal productivity of the farm factor would decline as production increases. That is, as output (Q) rises, F/Q rises. However, competitive producers would be willing to pay less for a less-productive farm factor, so that a rising farm output ratio should be accompanied by a rising retail-to-farm price ratio (P_r/P_f). A positive correlation between F/Q and P_r/P_f provides evidence of input substitution, and evidence in support of the revised retail-farm price margins proposed in equation 2.

Aside from diversity among firm technologies, diversity among final consumer food products also implies an F/Q ratio that responds to changes in relative factor prices.[5] To see this, suppose each identical firm in an industry produced the full array of diverse final consumer products associated with the particular food market. Suppose the energy-to-farm price ratio again increases. In this case, each efficient, identical, multiproduct firm will want to produce its output using higher proportions of the relatively less expensive farm ingredients. Each firm does this by producing relatively more of its existing high-farm-content products. The market clears as the industry offers more of these "low-processed" products to consumers at a lower relative price. Hence in response to a decrease in the relative farm price F/Q increases as the market allocates transactions across different final consumer food products.

A key to evaluating equation 2 is computing an estimate of composite consumer demand (Q). The challenge is to construct an estimate that reflects consumers' preferences for the diverse elementary products that they actually purchase.

The method of deflation provides one such estimate (Usher, 1971). Deflation defines Q as market-level consumer expenditures (E) divided by a market average retail price index (P_r), or

$$Q = E/P_r. \qquad (3)$$

Equation 3 indicates that Q is a value measure of composite demand expressed in base period dollars. Because E represents the sum of expenditures across different elementary products, a consistent estimate of equation 3 provides a measure of demand that reflects the value that consumers place on the diverse products that they actually purchase. An important question is whether equation 3 is a consistent estimate of consumer demand. This question relates to important issues of market definition. Recent theoretical work suggests that under fairly mild conditions, the "deflated" expenditure measure of Q represents a consistent estimate of composite, market-level consumer demand (Lewbel, 1996).[6]

To see the implications of equaiton 3 for market-level estimates of retail-farm price margins consider a correctly defined composite market that produces ($i = 1,\ldots,n$) different elementary products, so that consumer expenditures are

$$E = p_1 x_1 + p_2 x_2 + \ldots + p_n x_n$$

where p_i is the ith elementary price and x_i is the ith elementary quantity demanded. According to equation 3, the market-level output-input ratio is

$$Q/F = (E/P_r)/F = (p_1/P_r)(x_1/F_1) + (p_2/P_r)(x_2/F) + \ldots + (p_n/P_r)(x_n/F_1). \qquad (4)$$

Equation 4 reveals that the output-input ratio, or equivalently the inverse used in equation 2, is a relative-price-weighted sum of the different output-input ratios associated with the different products of the market. In the theory of retail-farm price margins, food products are conceptualized as bundles of farm and marketing services, so that a high (low) output-input ratio denotes a product with a high (low) marketing service component. Equation 4 illustrates that a composite market with a high output-input ratio is one in which consumers purchase high-priced, marketing-service-intensive products. Equations 2 and 4 suggest that retail-farm price margins rise as consumers shift from prod-

[5]The following description is more formally stated in Wohlgenant (1999).

[6]Appendix D discusses the tests for each of the seven markets in this study. Based on these tests, we could not reject the notion that each market represents a composite.

ucts with high farm components to products with high marketing service components.

One advantage of appealing to an expenditure-based measure of composite demand is that it provides a clearly defined measure of *quality*. If equation 3 is a consistent estimate of composite demand, it can be decomposed into a *physical* measure of output and a corresponding measure of quality (Usher, 1971; Nelson, 1991). For example, if one chooses to measure the physical dimension of consumer beef demand in pounds, quality would represent the value that consumers place on the countless number of other attributes of beef products (e.g., texture, flavor, convenience, nutritional content). In this case quality is defined as composite beef demand (i.e., equation 3) divided by the pounds of beef purchased. Notice that while clearly defined, quality always depends on the single physical dimension chosen (Nelson, 1991).

The willingness of agricultural economists to use *commercial disappearance* (e.g., Huang, 2000) as the physical measure of food demand suggests that they are implicitly willing to measure quality in terms of all of the attributes of food except the farm ingredient.[7] In this study, we call the collection of these other attributes (e.g., flavor, convenience, processing) "marketing services" and measure it as *Q/F*. Hence our approach allows us to interpret the inverse of *F/Q* used in equaiton 2 as food quality. Equation 4 illustrates that consumers have considerable choice in their determination of food quality through the purchases of different elementary products. Moreover, the new estimates given by equation 2 indicate that for a given set of farm and retail prices, increases in food quality are reflected in increases in retail-farm price margins.

In this study, we compute new estimates of retail-farm price margins (*M*) and compare them to *S*. Differences trace to differences in accounting for the quality of composite output arising from technological change, heterogeneous responses of firms, and the diversity of elementary consumer food products.

[7]Commercial disappearance estimates pertain to farm ingredients as they are derived from farm-level supply-utilization tables (see Putnam and Allshouse, 1999).

Empirical Results

This section describes data requirements, reports estimates of *M* and *S* for the at-home beef, pork, poultry, eggs, dairy, fresh fruit, and fresh vegetable markets, interprets differences between the series, and presents empirical evidence that support the new estimates.

The new retail-farm price estimates (*M*) given by equation 2 can be written in an equivalent form that is convenient for computation. Since equaiton 3 implies $E = P_r Q$, and farm receipts are $FR = P_f F$, equation 2 can be rewritten as

$$M = (E - FR)/Q. \qquad (5)$$

Equation 5 states that the new retail-farm price spread is the ratio of an industry's marketing bill to composite consumer demand.[8] We use equation 5 to compute empirical estimates of the revised retail-farm price estimates.

Note that we are computing estimates of market-specific price spreads, so that necessarily they apply to at-home price spreads.[9] Hence the variables *E*, *FR*, and *Q* in equation 5 refer to *at-home* consumer expenditures, farm receipts (i.e., receipts generated from *at-home* food sales), and *at-home* consumer demand, respectively.[10]

Table 1 reports the annual estimates of the *M* and *S* series over the 1980-97 sample for the seven composite markets. *M* is computed from equations 3 and 5, and *S* refers to the currently reported ERS estimates that can be thought of as adjusted versions of equation 1. Both estimates are expressed in index form.

Figures 1-7 present scatter plots of logs of input-output quantity ratios (Q/F) against logs of output-input price ratios (P_r/P_f).[11] Except for the beef market (figure 1), the positive-sloped regression lines shown in figures 2-7 provide evidence of input substitution. The negative-sloped regression line for beef (figure 1) may suggest structural change in the form of plant improvements that lead to the utilization of inputs in different proportions. Hence figures 1-7 suggest the new estimates could be justified on the basis of structural change for beef and input substitution in the other six markets.

Figures 8-14 present time plots of the *M* and *S* estimates over the sample period. These plots reveal some very general patterns across the seven markets. In particular, they illustrate that while *M* and *S* follow similar upward trends, *M* appears to be more volatile than *S* in every market. Moreover, there appear to be clear intervals over which *M* systematically differs from *S*. For example, figures 8 (beef), 9 (pork), and 14 (fresh vegetables) reveal extended periods over which the revised series (*M*) lies systematically above the existing series (*S*). This means that $F/Q < \theta$ or that proportionately more marketing-service-intensive products were purchased in these markets than the current ERS estimates suggest. On the other hand, figure 13 (fresh fruit) reveals that, over most of the sample, *S* systematically exceeds *M*, or $F/Q > \theta$. In this case, the new estimates suggest that consumers purchased more farm-intensive fresh fruit products than the current ERS estimates suggest.

Because F/Q for a composite market depends on consumer expenditure patterns for a market's diverse elementary products (i.e., equation 4 above), one would expect *M* to be more volatile than *S*. With the exception of eggs, Figures 8-14 show the relationship between the new estimates (*M*) for a composite market and its component expenditures. Overall, the figures

[8]The data and the data sources used to construct the variables of equation 5 are described in detail in the Appendix.

[9]The reason is that we can identify the main farm ingredient. For at-home purchases in these markets, consumers are purchasing a fairly well defined food bundle comprised of the farm ingredient and marketing services. In contrast, it is difficult to conceptualize, for example, a retail-farm price margin for away-from-home beef because the bundle demanded is a meal consisting of a number of different foods produced from a number of different farm ingredients. Nevertheless, the consumption of away-from-home beef has a direct impact on the corresponding at-home beef margins because final beef consumption competes for the same farm supply.

[10]The computational problem is obtaining estimates of farm receipts generated from at-home food sales. The results are based on estimates of farm receipts adjusted by a longrun point estimate of the proportion of farm receipts generated from at-home food sales for each industry (see Appendix E). However, this proportion may have declined over the sample period. In an attempt to capture the changing proportion, we adjusted the industry-specific point estimates by the observed declining proportion of food sales spent on at-home consumption (Putnam and Allshouse, 1999). This did not noticeably alter the empirical results reported here.

[11]The scatter points plotted in these figures are the OLS residuals of $ln(F/Q)$ regressed against a constant and time trend (T) (on the y-axis) against the residuals of $ln(P_r/P_f)$ regressed against a constant and T (x-axis). In other words, the scatter points represent logs of price and quantity ratios with both the mean and trend removed. By the law of iterated projections (e.g., Sargent, 1987), the slope coefficients associated with these scatter points reported in figures 1-7 equal the OLS estimate of β_2 in the model $ln(F/Q) = \beta_o + \beta_1 T + \beta_2\, ln(P_r/P_f)$.

Table 1—Current (S) and new (M) estimates of retail-farm price spreads (1982-84=100)

	Beef		Pork		Poultry		Eggs	
	S	M	S	M	S	M	S	M
1980	91.10	68.60	87.00	88.45	91.50	87.89	89.00	79.69
1981	99.10	95.65	93.40	68.76	100.7	93.59	90.40	84.96
1982	100.9	90.48	97.50	55.88	101.3	108.8	97.40	99.87
1983	100.9	84.45	106.8	94.33	97.60	75.77	95.10	92.05
1984	98.30	125.1	95.60	149.8	101.1	115.4	107.4	108.1
1985	104.9	132.5	104.0	176.7	106.6	123.6	100.4	126.0
1986	105.5	141.1	109.4	168.8	113.3	107.0	106.0	131.6
1987	103.4	122.0	121.4	171.4	134.2	160.2	117.9	157.3
1988	105.7	89.54	133.7	192.6	132.9	102.5	124.9	173.5
1989	112.1	137.5	131.6	197.1	150.6	119.8	138.1	174.7
1990	116.7	146.6	145.7	214.6	161.1	169.4	153.2	157.1
1991	132.8	173.9	157.1	262.2	164.9	220.5	157.6	173.7
1992	127.3	173.5	154.5	302.6	163.0	214.4	163.2	189.4
1993	134.0	204.3	147.3	294.1	166.2	219.5	167.8	194.7
1994	142.4	235.1	161.2	331.9	172.6	233.2	169.4	207.6
1995	151.3	260.2	151.8	333.3	177.7	244.9	173.2	218.2
1996	150.6	275.2	159.6	323.4	182.6	229.9	191.4	208.1
1997	147.5	253.6	177.7	335.4	198.1	250.9	213.0	217.1

	Dairy		Fresh fruit		Fresh vegetables	
	S	M	S	M	S	M
1980	85.90	59.34	84.20	76.05	81.30	—
1981	93.20	64.65	88.60	83.57	89.80	—
1982	97.30	85.80	97.00	96.38	93.90	69.53
1983	99.50	79.02	99.90	94.53	97.90	56.54
1984	103.2	135.2	103.3	109.1	108.2	173.9
1985	110.5	121.2	121.9	120.1	108.9	280.1
1986	113.3	127.5	128.0	125.3	116.8	284.5
1987	117.5	131.8	145.7	141.5	127.7	388.9
1988	124.7	137.0	158.7	151.9	141.3	444.7
1989	130.8	178.0	176.0	162.5	153.2	463.2
1990	149.5	175.7	195.9	182.4	164.9	462.4
1991	157.4	186.6	212.6	207.8	176.8	603.2
1992	158.7	167.2	220.6	194.2	177.1	598.8
1993	162.9	183.5	224.0	205.3	189.7	516.2
1994	166.2	173.4	250.1	216.7	200.2	566.1
1995	170.3	186.8	268.7	235.9	225.5	574.6
1996	174.3	207.9	285.2	254.0	228.3	787.9
1997	189.3	219.4	295.0	251.1	233.6	721.1

Figure 1

Quantity vs price ratios, beef

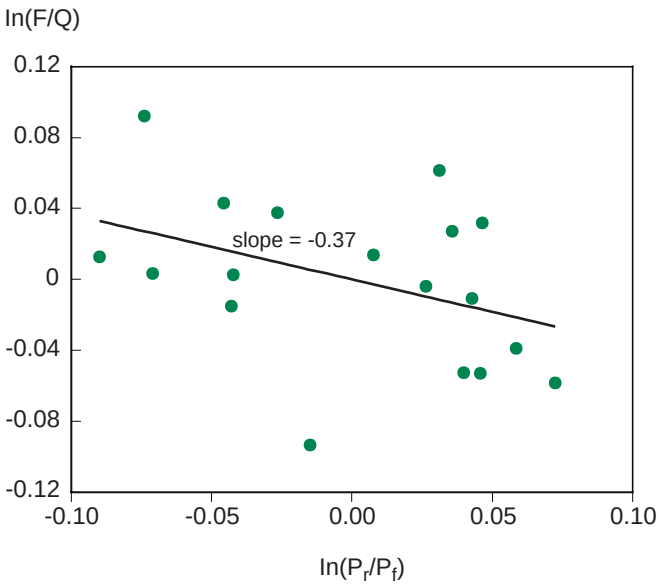


Figure 2

Quantity vs price ratios, pork

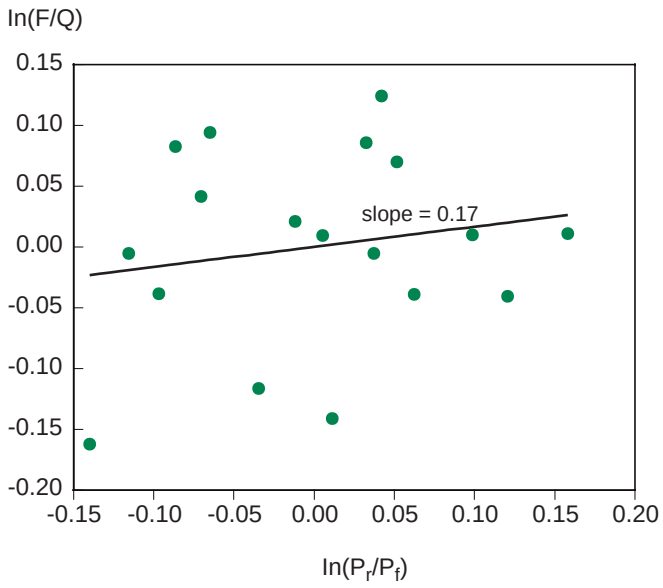


Figure 3

Quantity vs price ratios, poultry

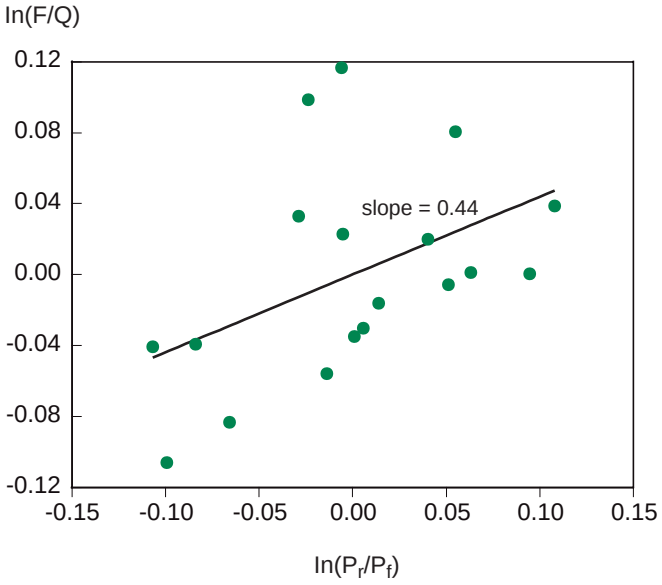


Figure 4

Quantity vs price ratios, eggs

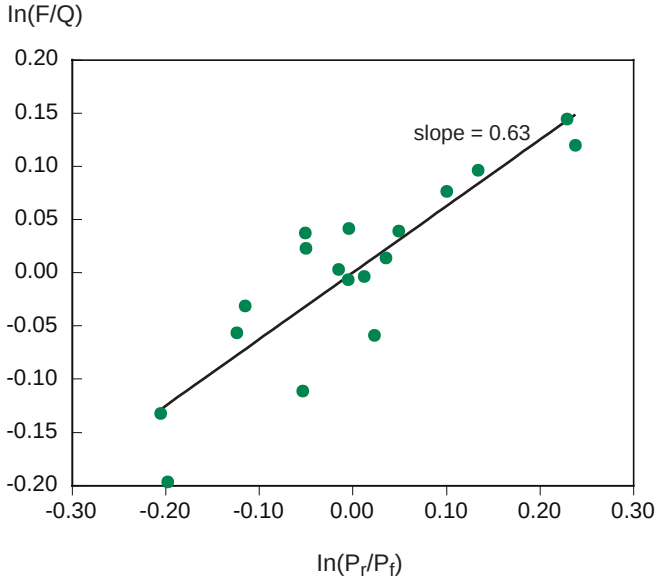


Figure 5

Quantity vs price ratios, dairy

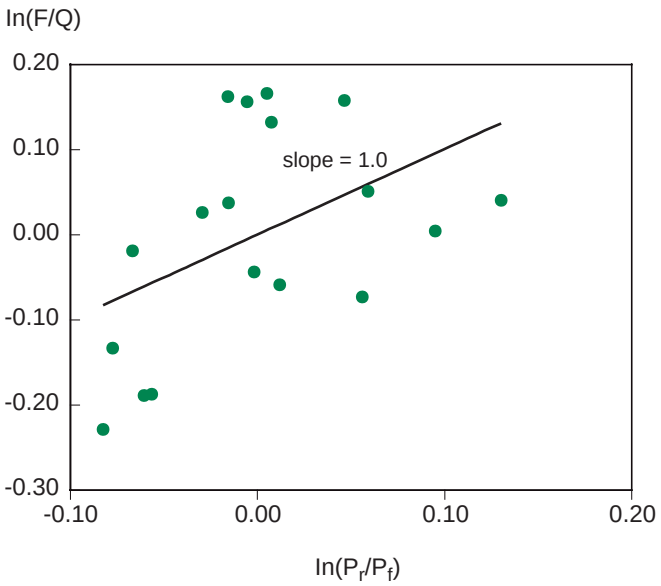


Figure 6

Quantity vs price ratios, fresh fruit

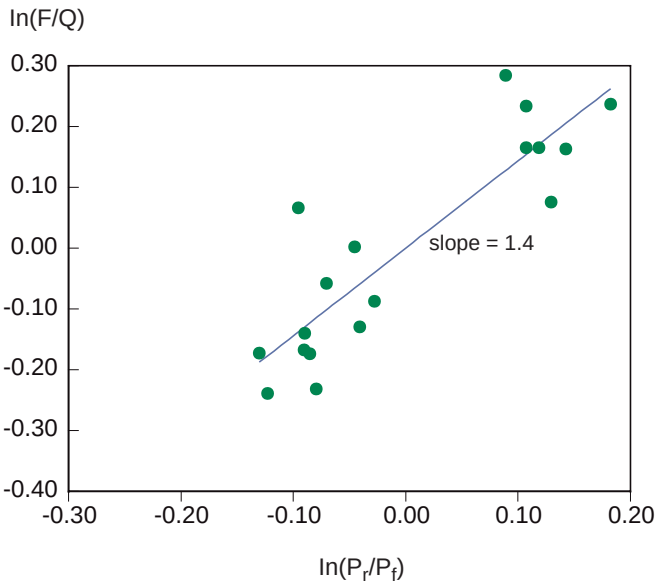
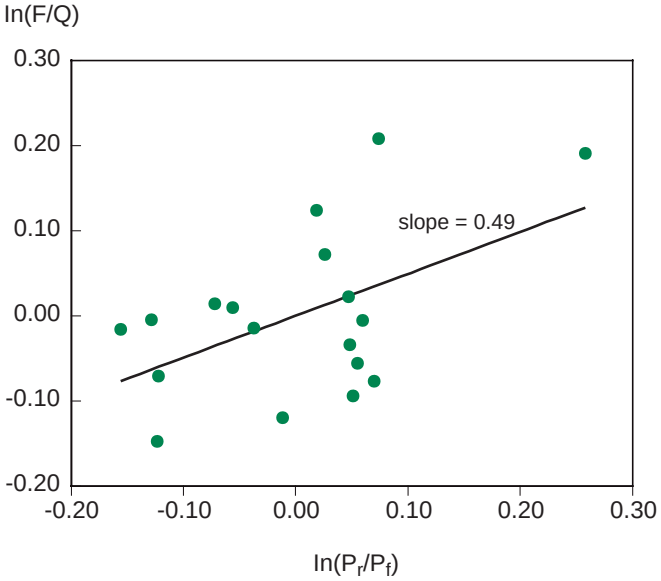


Figure 7

Quantity vs price ratios, fresh vegetables



demonstrate that the divergence between *M* and *S* is correlated with consumers' changing expenditure patterns for the component products of the composite market. The correlation is most transparent for the beef, pork, and poultry markets.

In the beef market, figure 8 illustrates that *M* begins to rise rapidly in 1988 and diverges from *S* over most of the remainder of the sample period. Figure 8a reveals that sirloin steak has been a relatively high-priced beef product over the sample. Figure 8b shows that one reason for the divergence of *M* from *S* is that, from 1988 through 1997, consumers chose to purchase farm-level beef in the form of relatively high-priced sirloin steak.

In the pork market, figure 9 illustrates that *M* exceeds *S* over most of the sample period. Figure 9a reveals that ham is a relatively high-priced pork product, and figure 9b suggests that the willingness of consumers to purchase farm-level pork in the form of relatively high-priced ham has contributed to $M > S$ over the sample. The increasing proportion of high-priced chop expenditures from 1991 to 1996 has also contributed to $M > S$.

Figure 8

Retail-farm price margins, beef

1982-84=100

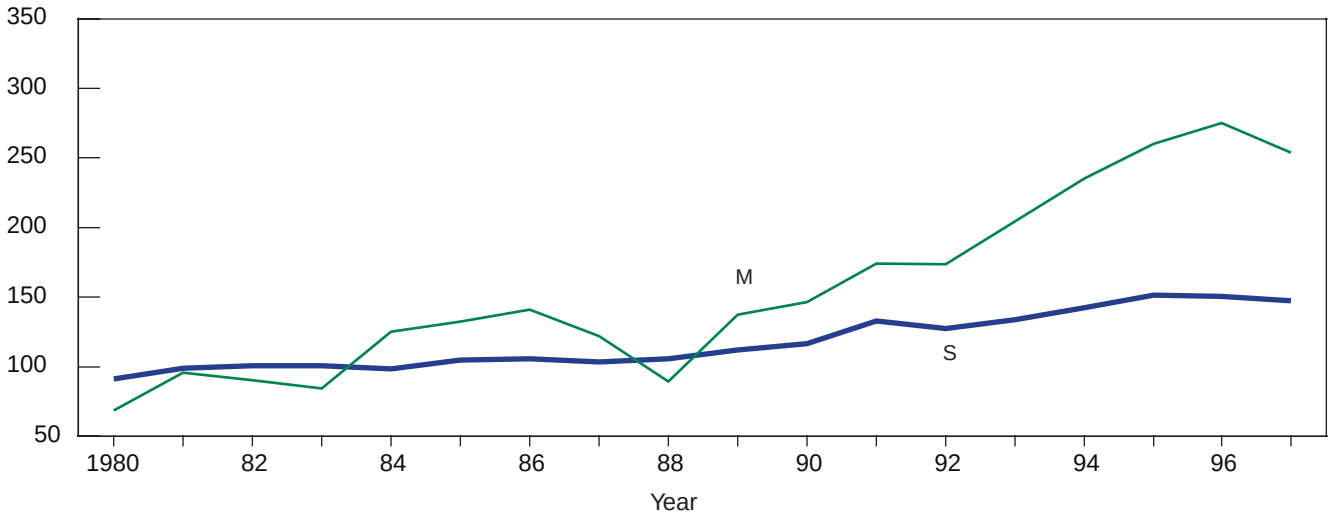


Figure 8a

Relative elementary prices, beef

1982-84=1.0

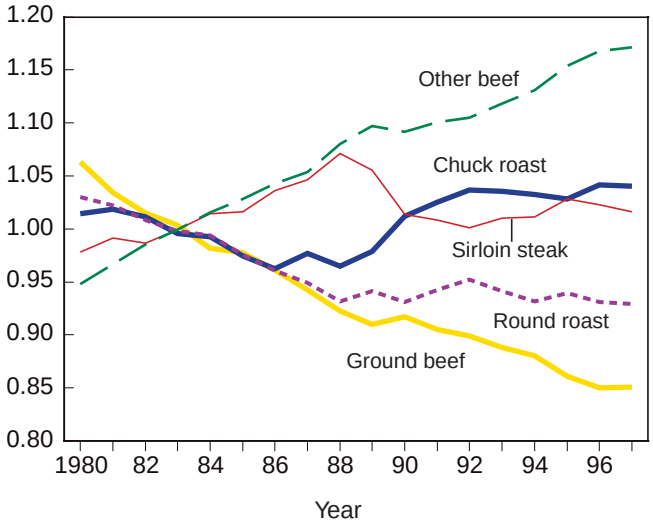


Figure 8b

Elementary output-input ratios, beef

1982-84=1.0

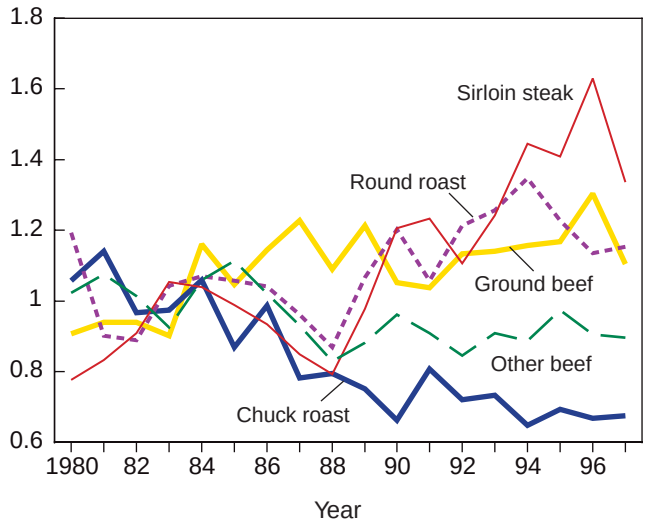


Figure 9

Retail-farm price margins, pork

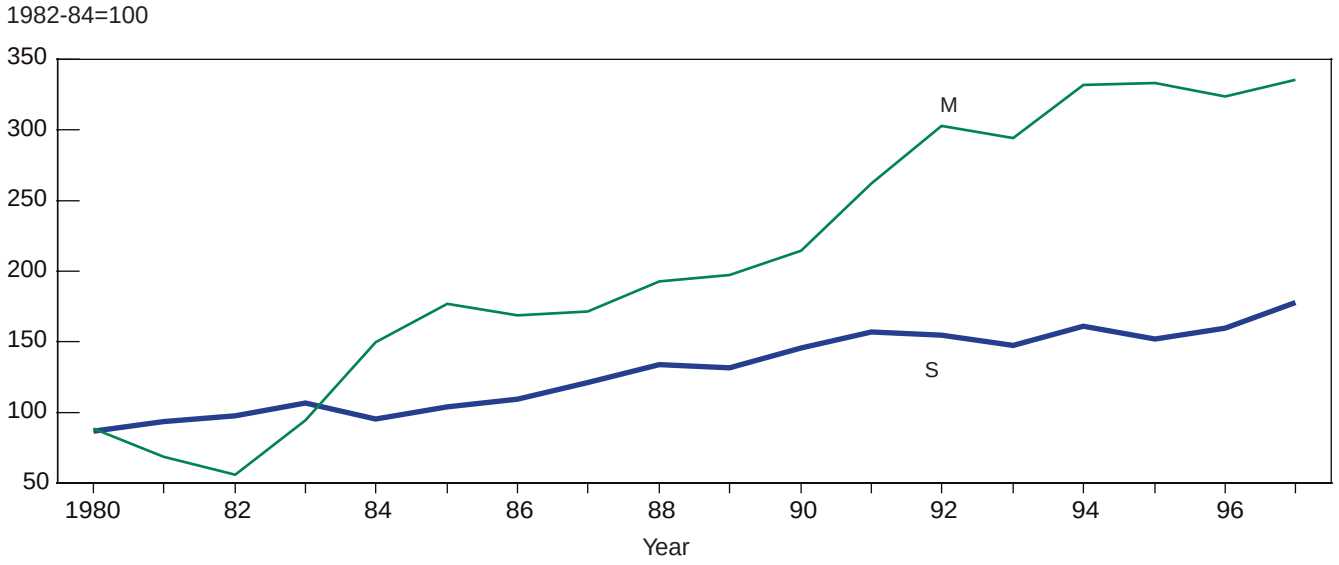


Figure 9a

Relative elementary prices, pork

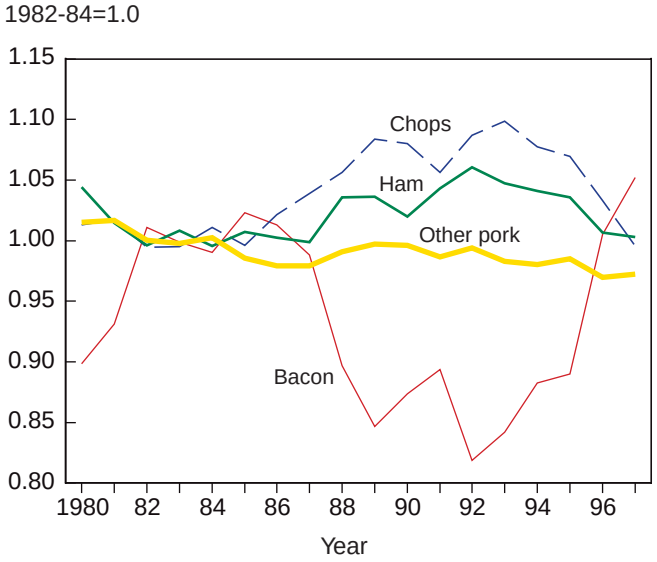
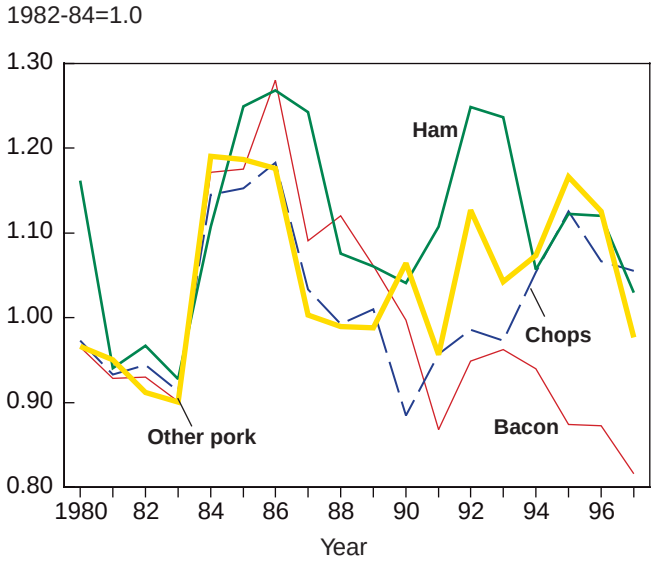


Figure 9b

Elementary output-input ratios, pork



In the fresh poultry market, figure 10 illustrates that *M* rose and remained above *S* from 1990-97. Figures 10a and 10b reveal that, after 1990, chicken parts became the highest priced poultry component. The willingness of consumers to purchase relatively high proportions of poultry in the form of chicken parts over this period has contributed to $M > S$. Also, from 1990-97 the relative price of other poultry rose, so that the willingness of consumers to purchase a high proportion of other poultry also contributed to $M > S$ after 1990.

Despite the different patterns, column 1 of table 2 suggests the correlation between the levels of *M* and *S* in each market is close to one. Moreover, the estimates reported in column 1 imply that one cannot reject the null hypothesis (at the 0.01 level of significance) that the levels of the two estimates are correlated.[12] The results are surprising in light of the differences between equations 1 and 2. However, the high correla-

[12] The estimates in table 2 are Spearman rank correlation coefficients.

Figure 10

Retail-farm price margins, poultry

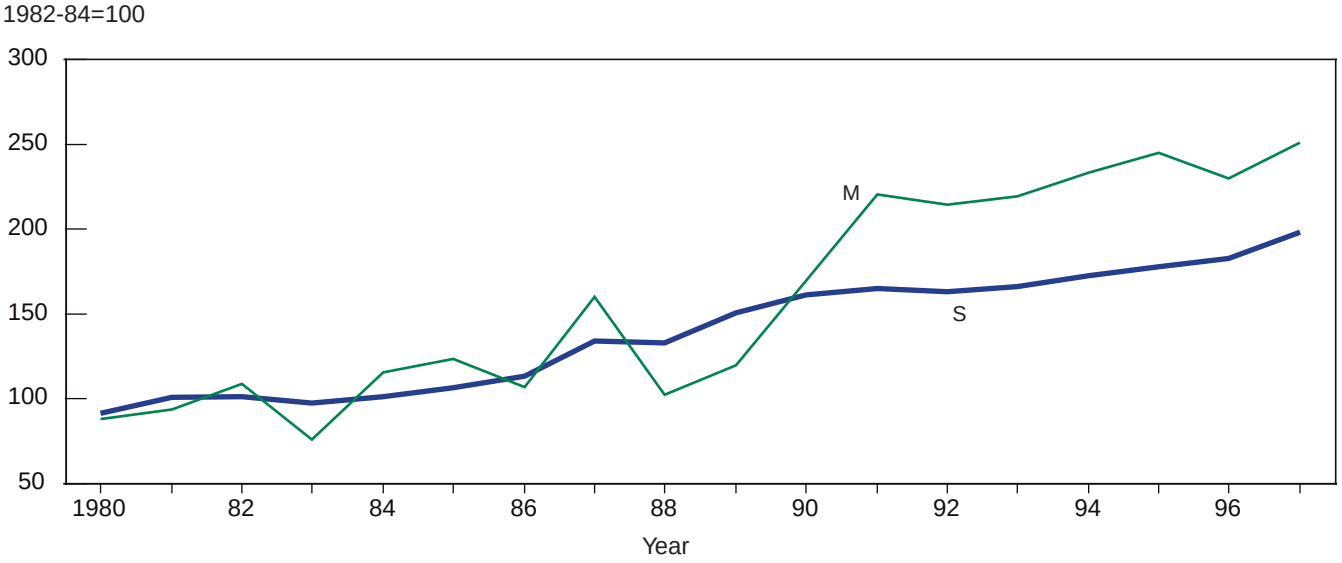


Figure 10a

Relative elementary prices, poultry

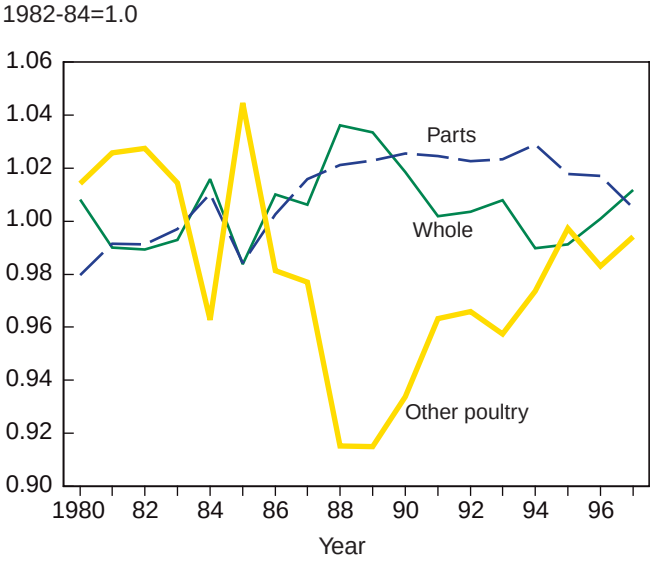


Figure 10b

Elementary output-input ratios, poultry

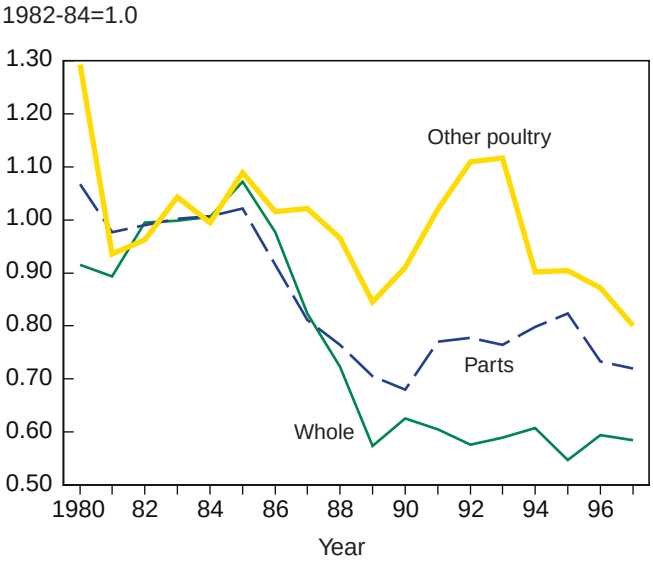


Table 2—Spearman rank correlation estimates between M and S

	Levels	Time trend removed	Annual difference
Beef	0.919**	0.663**	0.500*
Pork	0.936**	-0.185	0.159
Poultry	0.944**	0.430	0.549*
Eggs	0.971**	-0.519*	-0.223
Dairy	0.940**	-0.102	0.069
Fresh fruit	0.990**	-0.661**	0.505*
Fresh vegetables	0.961**	-0.387	-0.037

** Reject zero correlation at the 0.01 level.
* Reject zero correlation at the 0.05 level.

tion might be explained in two ways. First, as stated above, while the current estimates reported are based on a fixed input-output ratio (θ in equation 1), this fixed factor is periodically adjusted for beef and pork. For all other markets, however, more frequent adjustments are made to equation 1 to account for changing consumer expenditures. Second, a high correlation between the series may be attributed to the strong trends displayed by both series over the period. Such trends can mask important differences in the response of the two series to market changes.

Columns 2 and 3 of table 2 report estimates of correlation between *M* and *S* that attempt to control or remove these trends. Column 2 reports correlation estimates after both the mean and the trend are removed from both series.[13] It is noteworthy that Column 2 reports a negative or a statistically insignificant (at the 0.05 level) correlation between *M* and *S* for every market except beef.

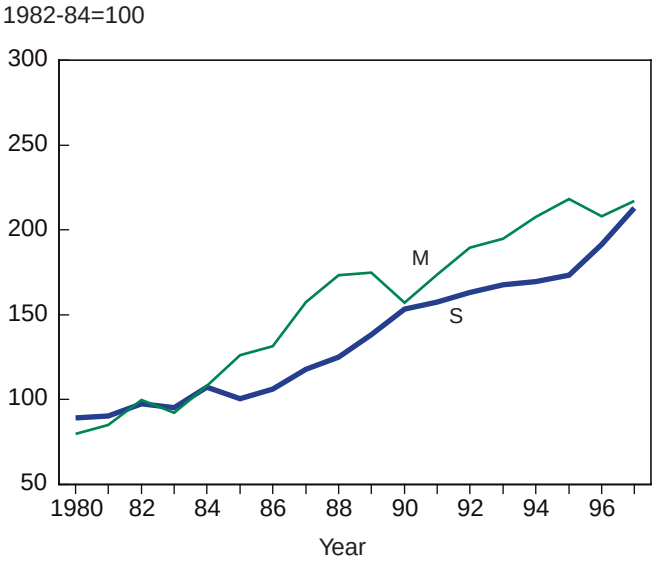
Column 3 reports correlation estimates between annual changes (i.e., first differences) in the series. Column 3 reports either a negative or a statistically insignificant correlation for every market except the beef, poultry, and fresh fruit markets. The results reported in columns 2 and 3 suggest that, with the exception of beef and possibly poultry and fresh fruit, the new estimates respond differently to changing market conditions than the current estimates.

In the previous section, we pointed out that expenditure-based measures of consumer demand lead to a precise measure of food quality that links directly to the new estimates. In particular, equation 2 suggests

[13]The residuals from of each series regressed against a constant and linear time trend are used to compute the correlation estimates.

Figure 11

Retail-farm price margins, eggs



that, conditioned on farm and retail prices, increases in quality translate into increases in *M*. Moreover, estimates of *S* based on a strictly fixed output-input parameter would not respond to changes in food quality.

Figures 15-28 graph the annual percent change in the current ERS estimates (*S*), the annual percent change in *M*, and the annual percent change in quality (*Q/F*). These graphs illustrate that changes in *M* appear to be more frequently "in-phase" with changes in quality over the sample period than do changes in *S*. In markets such as pork, changes in the current ERS estimate appear to be "out-of-phase" with changes in quality (figure 17). These results suggest that the new estimates of retail-farm price ratios are more sensitive to changes in food quality than the current ERS estimates.

Figure 12

Retail-farm price margins, dairy

1982-84=100

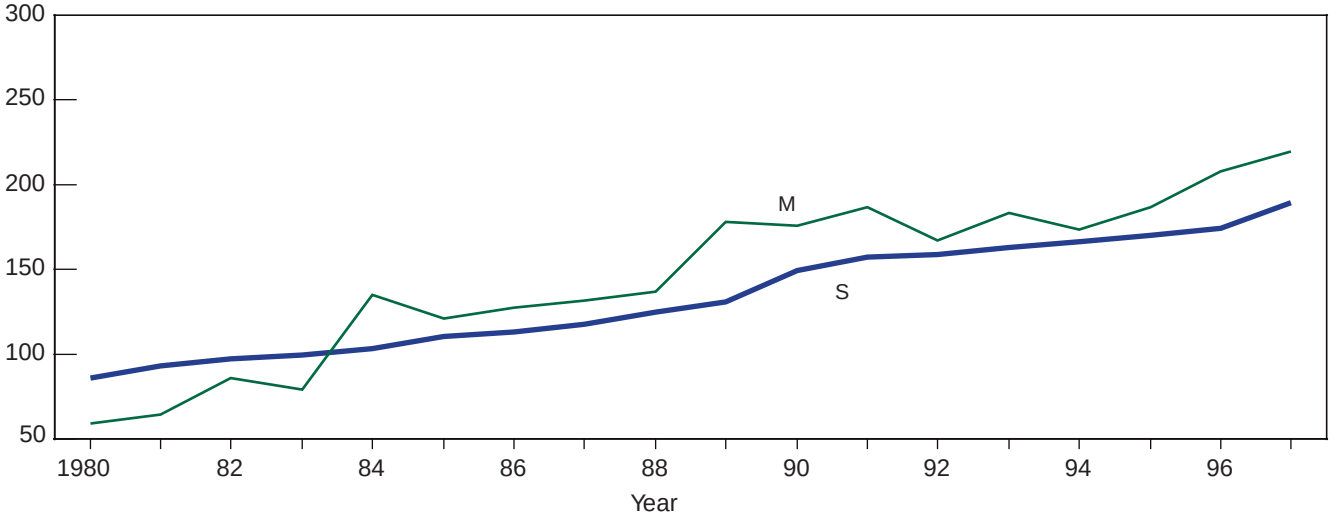


Figure 12b

Relative elementary prices, dairy

1982-84=1.0

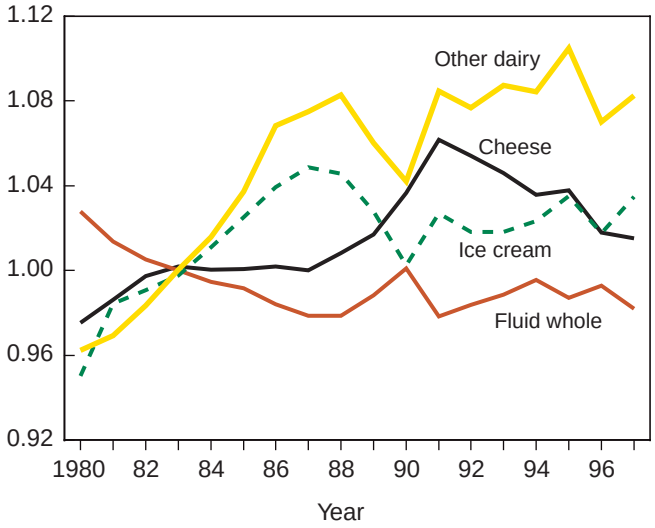


Figure 12c

Elementary output-input ratios, dairy

1982-84=1.0

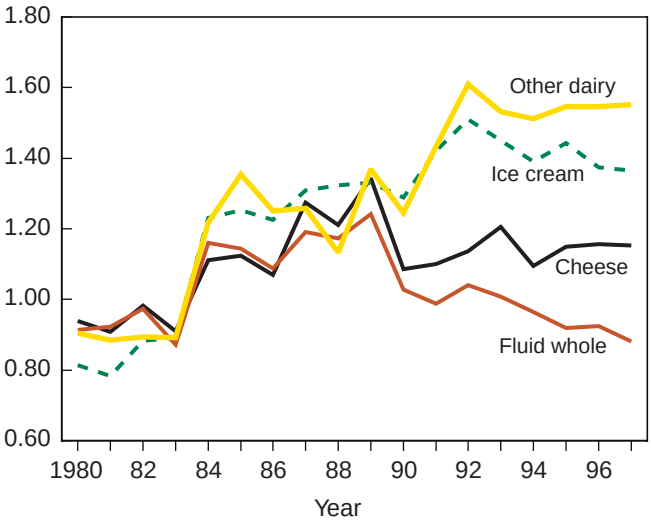


Figure 13

Retail-farm price margins, fresh fruit

1982-84=100

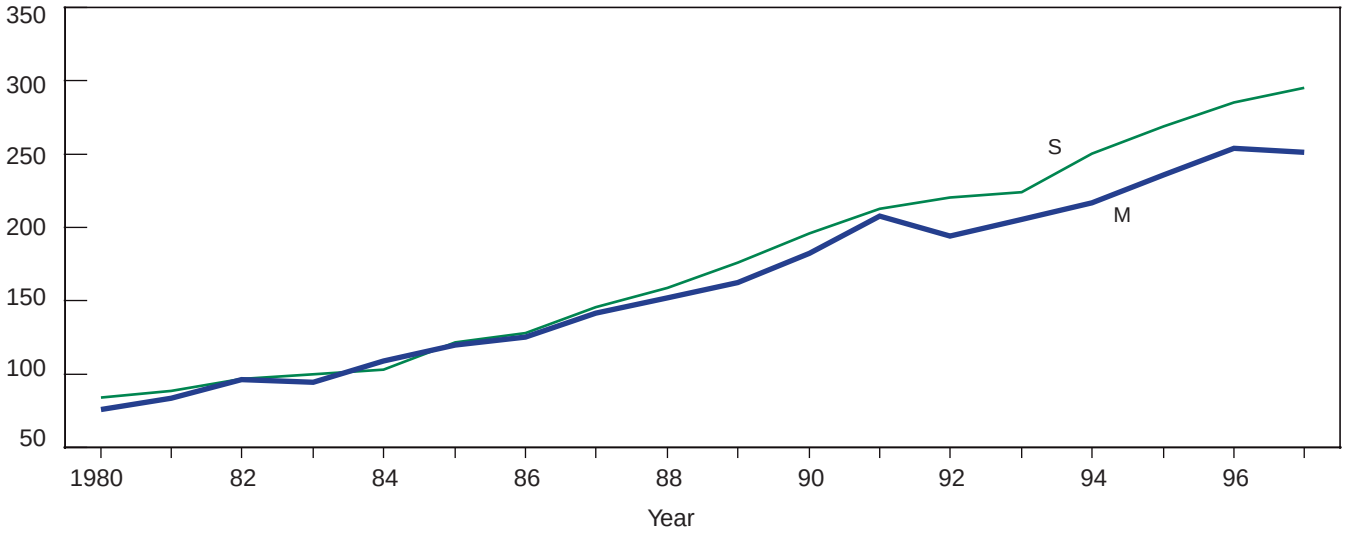


Figure 13b

Relative elementary prices, fresh fruit

1982-84=1.0

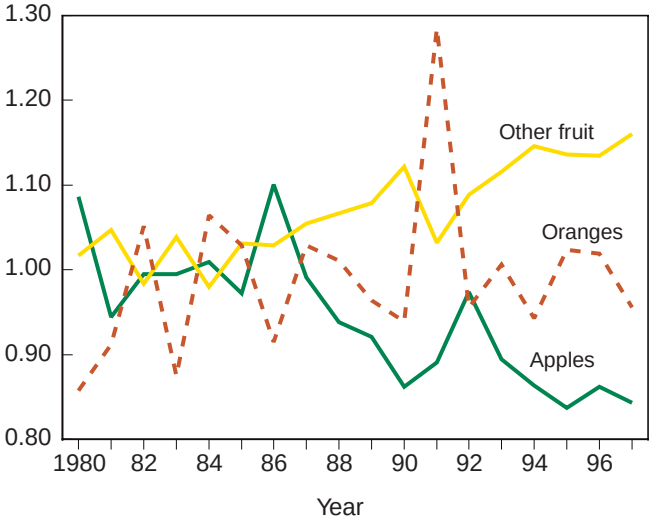


Figure 13c

Elementary output-input ratios, fresh fruit

1982-84=1.0

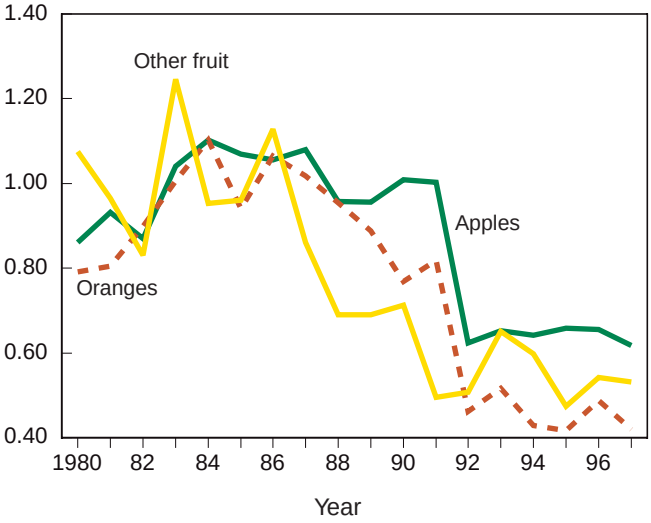


Figure 14

Retail-farm price margins, fresh vegetables

1982-84=100

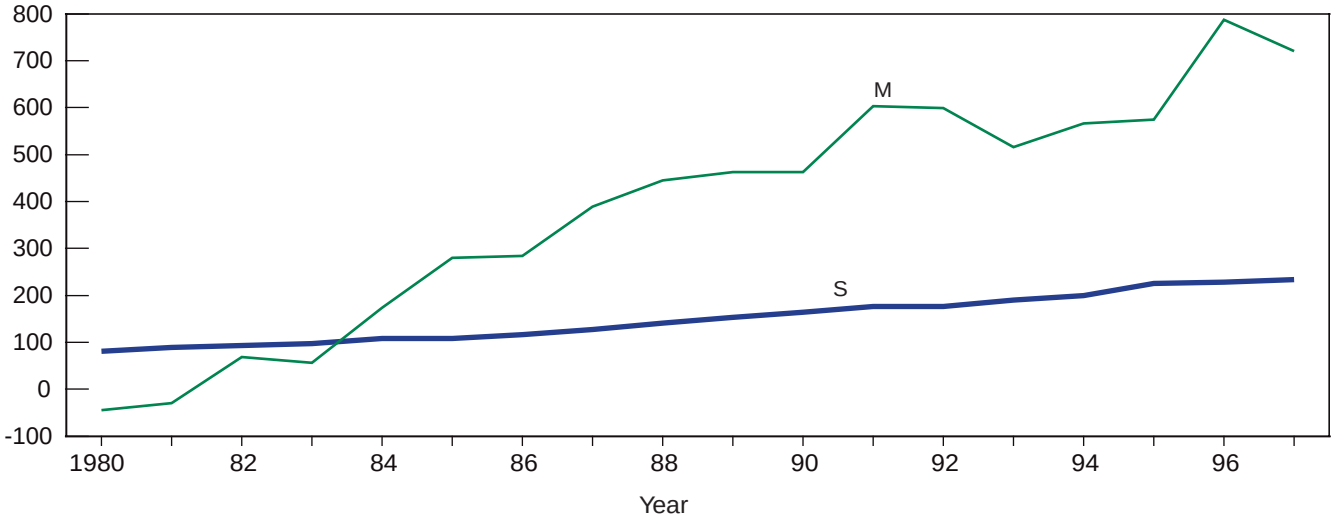


Figure 14b

Relative elementary prices, fresh vegetables

1982-84=1.0

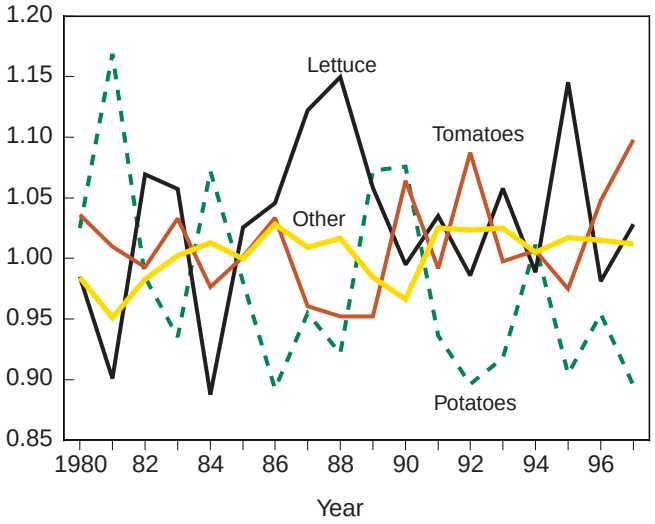


Figure 14c

Elementary output-input ratios, fresh vegetables

1982-84=1.0

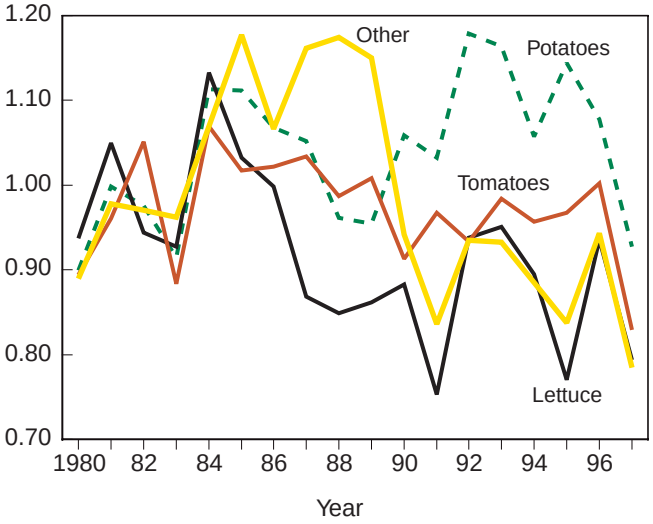


Figure 15

Percent change in S and quality, beef

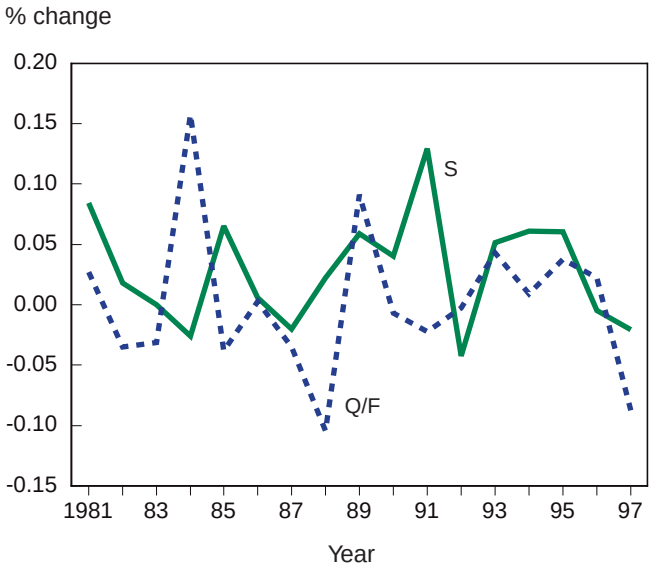


Figure 16

Percent change in M and quality, beef

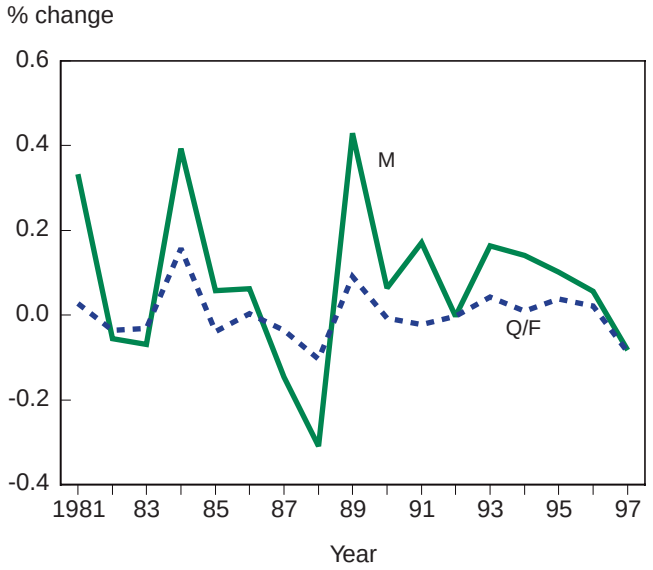


Figure 17

Percent change in S and quality, pork

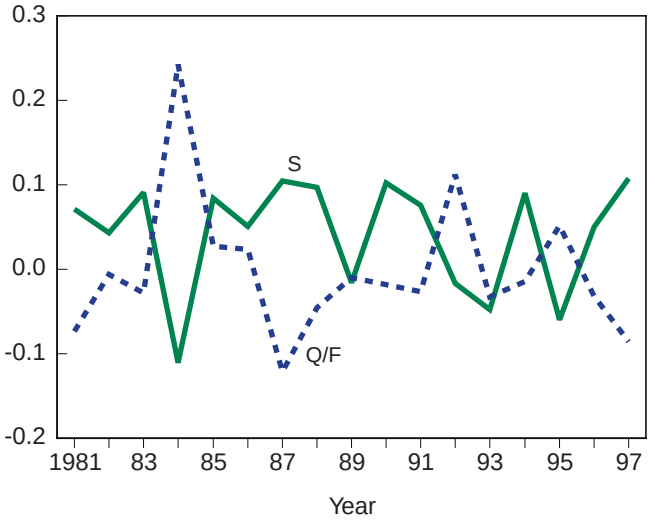


Figure 18

Percent change in M and quality, pork

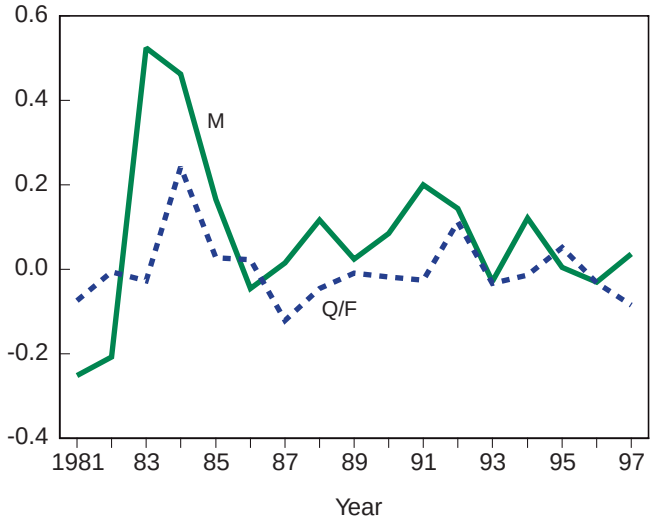


Figure 19

Percent change in S and quality, poultry

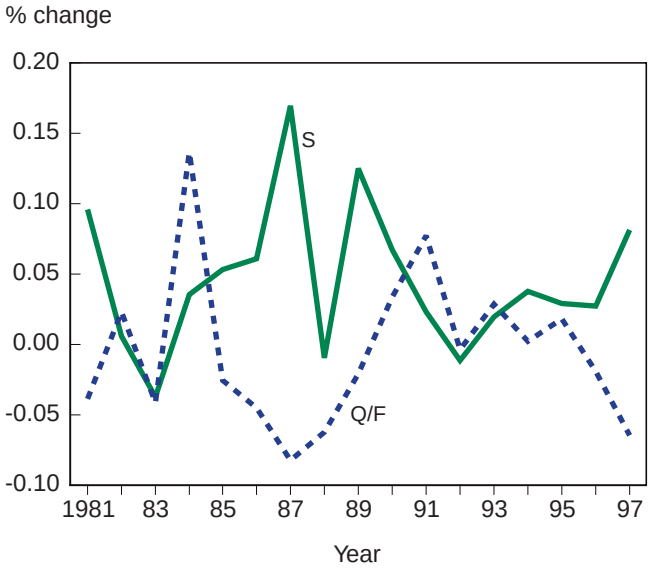


Figure 20

Percent change in M and quality, poultry

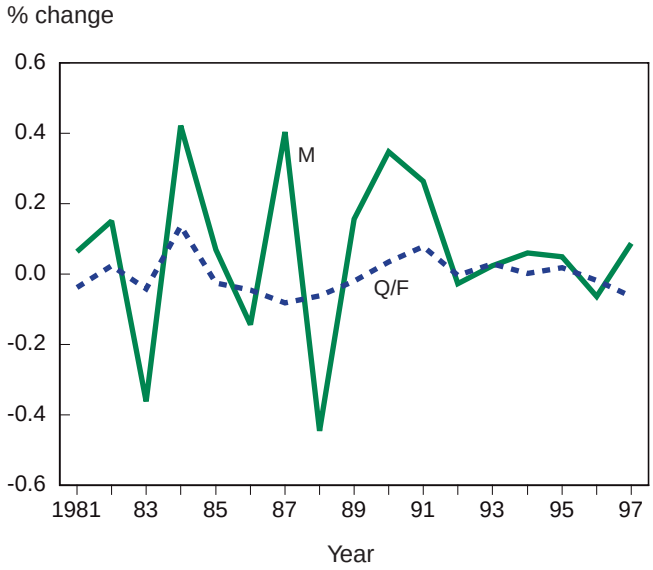


Figure 21

Percent change in S and quality, eggs

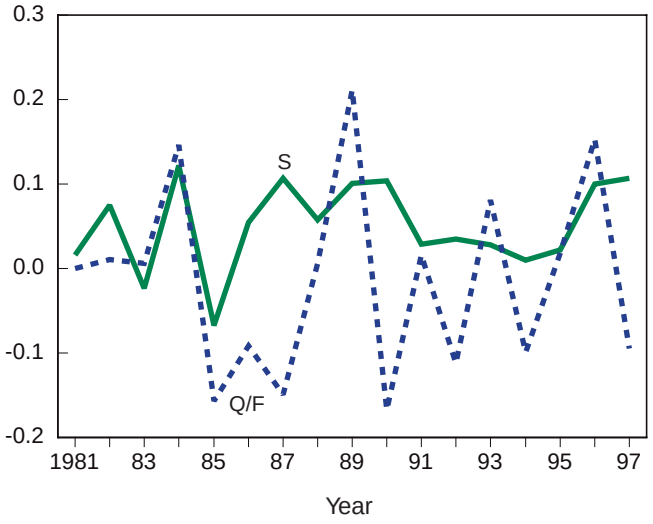


Figure 22

Percent change in M and quality, eggs

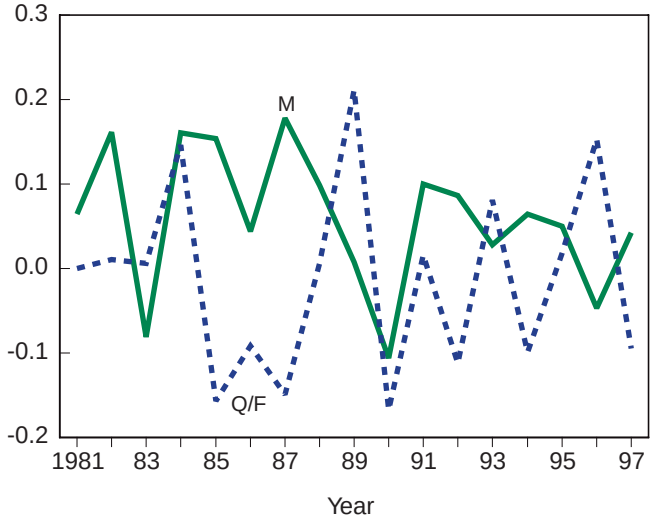


Figure 23

Percent change in S and quality, dairy

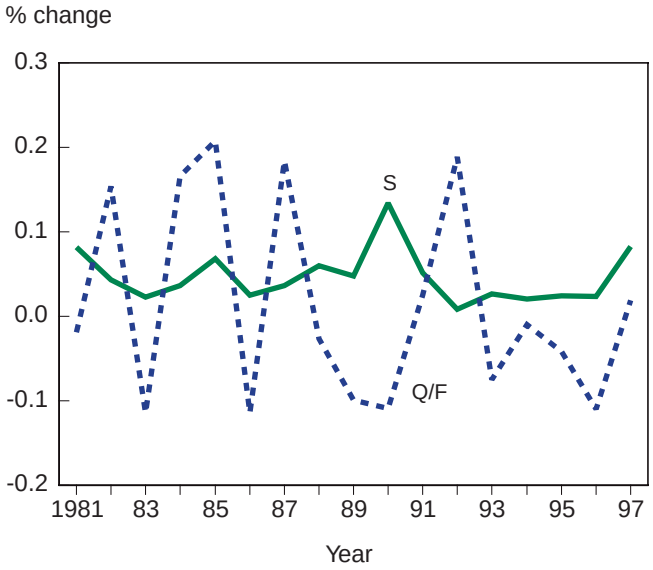


Figure 24

Percent change in M and quality, dairy

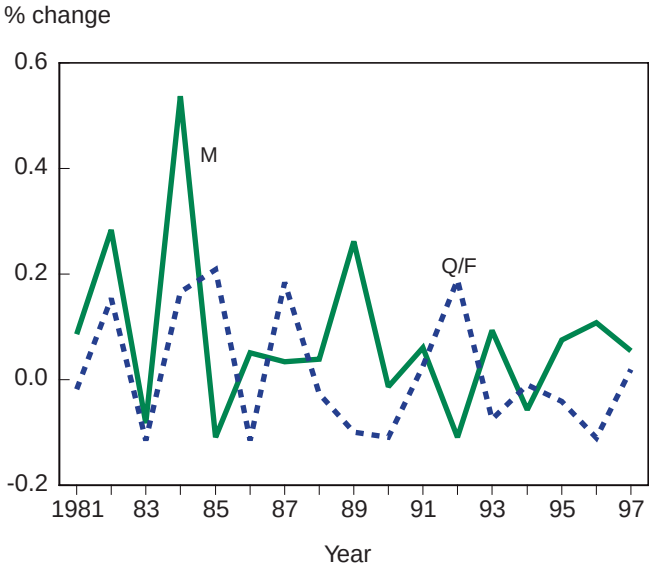


Figure 25

Percent change in S and quality, fresh fruit

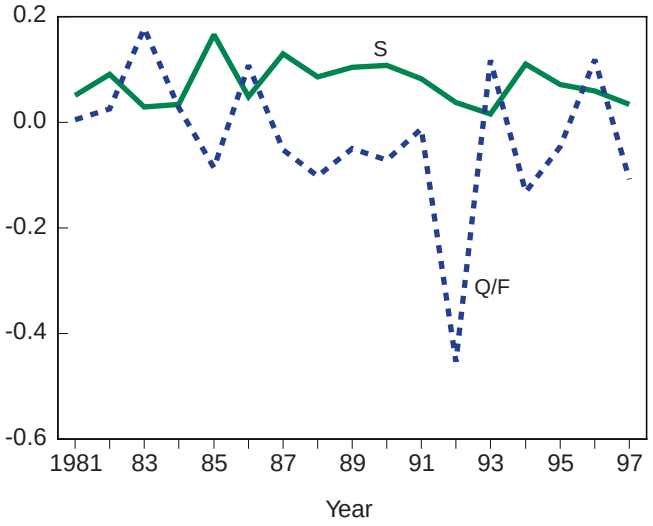


Figure 26

Percent change in M and quality, fresh fruit

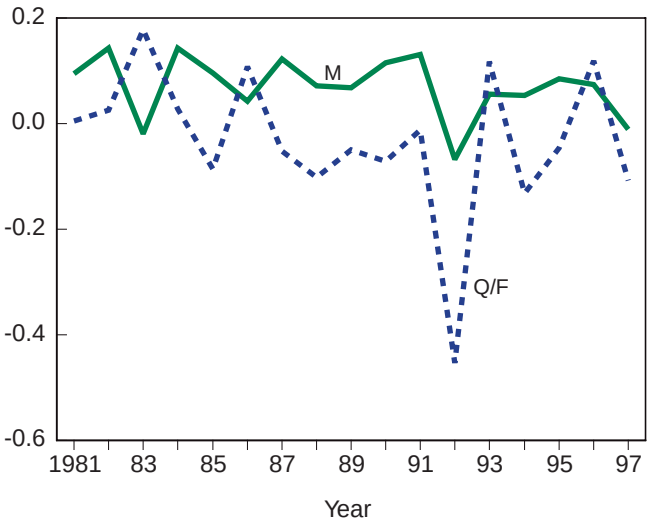


Figure 27

Percent change in S and quality, fresh vegetables

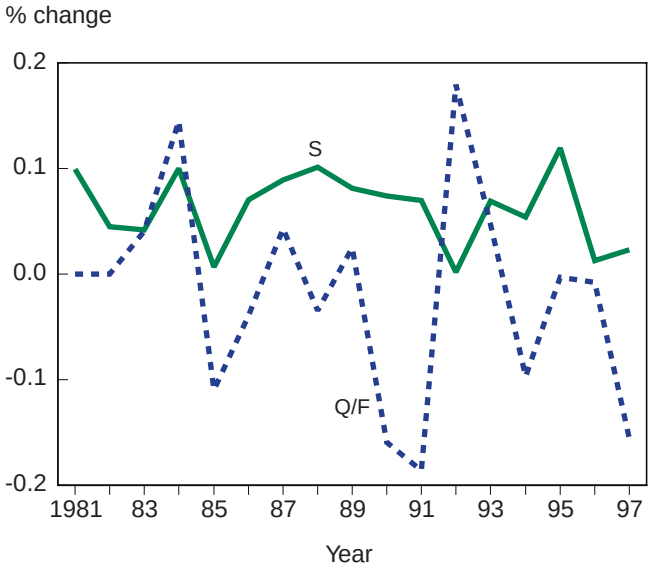
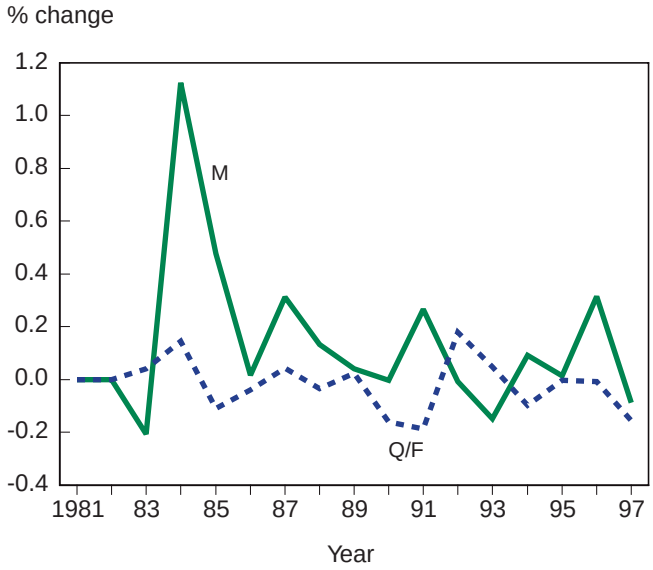


Figure 28

Percent change in M and quality, fresh vegetables



Conclusions

This study provides an alternative to USDA's estimates of retail-farm price margins for major U.S. food commodities. These new estimates automatically account for the implications of structural change, the diversity among firms, and the diversity of final products associated with a food market. In contrast, current USDA-ERS estimates fail to automatically account for diversity and structural change in food markets.

Without appealing to market power, both the current and new estimates for seven major U.S. food markets trend upward over the 1980-97 sample period. Although the new estimates appear to be more volatile than the current estimates, the two sets are highly correlated. More significant is the finding that the *responses* of the two sets of estimates are either not statistically correlated or are *negatively* correlated. These differences are explained by the differences in assumptions concerning diversity in food markets.

The new estimates allow for diverse firm-level responses to market changes, a feature that allows for input substitution as the industry allocates production across different firm-level technologies. The current estimates rule out this source of response by presuming identical firms. Also, the new estimates link rising retail-farm price margins and declining farm shares to changes in demand for the diverse elementary products that consumers actually purchase. Without invoking *ad hoc* adjustments, the current estimates cannot be linked to expenditures on the diverse array of final consumer food products. Expenditure-based measures of composite consumer demand are central to the computation of the new estimates because they directly link changes in demand for food quality and marketing services to changes in retail-farm price margins. Empirical results suggest that the new estimates are more sensitive to changes in the demand for food quality than the current estimates.

Improvements in the new series will emerge from improved estimates of the farm receipts generated from at-home sales. Because away-from-home sales compete for the same farm ingredients, continued growth in away-from-home demand is likely to increase the retail-farm price margins.

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Glossary of Terms

Composite demand. Composite consumer demand or output is a value measure of a group of related final (elementary) products that consumers actually purchase. For example beef, pork, or poultry might be considered a composite product. Establishing that a particular market satisfies conditions for a composite allows analysts to treat a group of diverse final products as a single good in every way. Retail-farm price margins are most meaningfully computed for composite food markets.

Diminishing returns. Diminishing returns to a factor of production means that, holding all other inputs constant, the marginal productivity of the factor declines as more of the factor is used in production. The feature of diminishing returns characterizes variable proportions production functions.

Elementary products. Elementary products are the final goods that consumers actually purchase and are associated with a composite market. For example, consumers purchase beef (i.e., the composite) through actual purchases of elementary products such as hamburger, soup bones, steak and processed beef products. In contrast to a composite output, elementary products are considered homogeneous and so can be measured in terms of physical units.

Fixed-proportions production. A fixed-proportions technology is characterized as one in which input-output ratios remain fixed regardless of changes in relative input prices. When fixed-proportions production is assumed to apply to a composite market, firms and consumer products are implicitly assumed to be homogeneous.

Marketing bill. The marketing bill for a food market is the difference between consumer expenditures for retail food products and the farm value (or receipts) of those products.

Retail-to-Farm Price Margin or Spread. The retail-farm price margin or spread is the value that the market places on the marketing service component of food. Price spreads for a competitive market are computed as the difference between the retail price and the retail-equivalent farm price. In a competitive market, it is the value that consumers place on attributes of food associated with the marketing service component; and it is also the marginal cost of that an industry faces in providing the marketing service component.

Variable-proportions production. A variable-proportions technology is characterized as one in which input ratios change with changes in relative factor prices. At the market level, variable-proportions is implied if firms or products are diverse. That is, even if each firm in an industry produces according to fixed-factor proportions, if the fixed factors vary across firms, variable-proportions production characterizes industry production.

Appendix

A. Data Sources

The Diary sections of Annual Consumer Expenditure Survey (CES) from 1980-97 are used to construct U.S. nominal expenditures (*E*) for each market. We apply BLS-supplied weights to each survey record (household) to compute national estimates. Source: Bureau of Labor Statistics, U.S. Dept. of Labor (BLS).

Supply and utilization (S&U tables) data are used to construct farm supply estimates. Source: Economic Research Service

Farm prices (P_f). Source: National Agricultural Statistics Service

Livestock byproduct adjustment data are used to compute estimates of farm receipts. Source: ERS.

Retail Prices (P_r). Consumer Price Index (CPI) data are used. Source: BLS.

B. General Description of the Computations of the Revised Retail-Farm Price Margins

As stated in the text, we compute estimates of the revised retail-farm price margin by evaluating both the numerator and denominator of equation 5. The U.S. consumer expenditure (*E*) for each market is obtained from weighted Consumer Expenditure Survey data (see above). According to the Generalized Composite Commodity Theorem (GCCT) and equation 3 in the text, *Q* is the ratio of nominal expenditures divided by an average price index for the composite market (i.e., P_r.). We use the BLS estimates of the CPI for the composite market as the price index.

To arrive at an estimate of farm cash receipts generated by domestic at-home food sales, exports and byproducts were subtracted from total receipts to generate a net receipt number. Finally an econometric estimate of the proportion of net farm receipts generated from away-from-home food sales was applied to net receipts to generate net farm cash receipts generated by domestic at-home food sales. This is *FR* in equation 5 in the text. Some of the market-specific computations are detailed in section C below.

Given *E*, *FR*, and *Q*, we compute the series M for each market according to equation 5 in the text. Note the result is a dimensionless number, so that M is expressed as an index (1982-84 = 100). The 1982-84 base period was chosen to coincide with the current base used to report both the CPI and the USDA market basket.

C. Market-Specific Computations

Beef and veal. Composite consumer demand for beef is computed by dividing U.S. annual beef expenditures (CES data) by the CPI for beef and veal. To compute adjustments to farm receipts, we treated the farm supply facing beef producers as homogeneous so that the prices received by beef farmers were independent of whether the cattle were sold to domestic channels or exporters. Hence quantity ratios constructed from ERS supply-utilization data served as adjustment factors to the total farm cash receipts. The export adjustment factor was computed by dividing export quantity by the quantity of total production. Byproducts were removed by means of data developed in conjunction with ERS Choice beef price spread estimates. The value of beef byproducts was divided by the gross farm value for Choice beef in order to calculate the byproduct adjustment factor. Procedures implemented to adjust for the away-from-home market are discussed below.

These procedures were also used to adjust the veal data for exports, byproducts, and away-from-home consumption. However, data for veal farm cash receipts are not reported separately. Therefore, it was necessary to estimate the ratio of adjusted beef and veal production to the farm value of total production based on the supply and utilization tables. This task was accomplished by multiplying the adjusted cattle quantity data by the farm price for cattle to obtain an estimated farm value. Similarly, the adjusted veal quantity was multiplied by the price received by farmers for calves. Total quantities of beef production were then multiplied by the cattle price, while total quantities of veal production were multiplied by the calf price. Estimated adjusted farm values for beef and veal were summed. Estimated aggregate farm values for beef and veal production were also totaled. Adjusted beef and veal farm values were divided by the farm value of total production for these two commodities. Cattle cash receipts were then adjusted by this ratio.

Pork. Composite consumer demand for pork is computed by dividing annual pork expenditures (CES data) by the CPI for pork. To compute adjustments to farm receipts, we treated the farm supply facing pork pro-

ducers as homogeneous. Hence, quantity adjustment factors were computed in the same way as they were for beef. Byproduct values were obtained from the ERS pork price spread series, and divided by the gross farm value for pork. This figure was multiplied by total hog production in order to remove the proportion of cash receipts allocated to byproducts.

Poultry. Composite consumer demand for poultry is computed by dividing annual poultry expenditures (CES data) by the CPI for poultry. To compute adjustments to farm receipts, we considered the chicken and turkey as separate farm commodities. Hence we combined these receipts using the same procedures we used for beef and veal. Byproducts constitute a negligible proportion of total cash receipts, and were therefore not estimated.

Eggs. Composite consumer demand for eggs is computed by dividing annual eggs expenditures (CES data) by the CPI for eggs. Eggs are perhaps the most homogeneous products of the seven commodity composites considered in this study. However, NASS data indicate that farmers receive higher prices for hatching eggs than for eggs destined for human consumption. Unfortunately, a price series for hatching prices is unavailable. Therefore, we can only partially adjust for hatching eggs by using the farm price for all eggs. The farm value of exports is computed by multiplying the quantity of exports by the price for table eggs. The quantity of hatching eggs is then multiplied by the farm price for all eggs. Next, total egg production is multiplied by the price for all eggs. The farm value of exports and hatching eggs are then deducted from the farm value of total production. This procedure does not adequately differentiate between market and nonmarket eggs when the total farm value is computed.

Dairy. Composite consumer demand for dairy is computed by dividing annual dairy expenditures (CES data) by the CPI for dairy products. To compute adjustments to farm receipts, we treated the farm supply, calculated on a milk-fat basis, as homogeneous and made similar quantity ratio adjustments to cash receipts as performed above.

Fresh fruits. Since bananas are imported, U.S. consumer expenditures for bananas (CES data) are subtracted from fresh fruit expenditures. Furthermore, the reported CPI for fresh fruit is adjusted so that it excludes the banana component. Hence composite consumer demand for fresh fruits is computed by dividing annual fresh fruit expenditures less banana expenditures divided by the adjusted CPI for fresh fruits. To compute adjustments to farm receipts, we recognized this category as highly heterogeneous. Moreover, the availability of data varies over time. Therefore, exports were removed by using approximately 12 major fruits and melons, which account for the majority of total American fruit consumption. For each selected fruit, exports and total production were each multiplied by the appropriate farm price, and summed across commodities. The estimated farm value of exports for all fruit were then divided by the farm value of total production, and applied to the cash receipts figure for fresh fruit. A special procedure had to be employed for citrus fruits. Citrus fruit production is reported in terms of short tons, while prices are presented in terms of dollars per box. The weight of each box varies, depending on the State where the fruit is grown. The average weight of each box was calculated by:

(1) Determining the percentage of total production in each producing State,
(2) Multiplying this percentage by the average weight of each box in a given State, as reported by NASS, and
(3) Summing the figures obtained in Step 2.

Fresh vegetables. Composite consumer demand for fresh vegetables is computed by dividing annual fresh vegetable expenditures (CES data) by the CPI for fresh vegetables. To adjust farm receipts, we recognized this category as very heterogeneous. Approximately 12 of the most important vegetables (in terms of total production) were used to remove exports from farm cash receipts. These vegetables were assumed to be representative of all vegetables in terms of the ratio of the farm value of exports to the farm value of total production. For each vegetable, estimated farm values were computed by multiplying by total export quantity and by total production. The resulting farm values for exports and total production were then summed across all vegetables. An aggregate ratio of export value to total production value was then used to remove foreign trade from the cash receipts.

D. Composite Commodity Tests

The question of whether at-home consumption of beef, pork, poultry, eggs, dairy, fresh fruit, and fresh vegetables represent valid composites is central to the computation of meaningful retail-farm price margins. The tests proposed by Lewbel are designed to address the question of whether there exists a set of composite or

group demands that accurately reflects consumer preferences for the elementary products that consumers actually purchase. The procedures are designed to test whether a variable formed as the log of the ratio of an elementary product price divided by the average price for the hypothesized group is independent of the deflated (by all food CPI) average price for the group. Evidence of pairwise independence between the log of the deflated elementary product price and the deflated average price is a necessary condition for the existence of a valid composite.

Given that unit roots appeared to be driving most of the data, five tests of cointegration represent tests of pair-wise independence. Two are designed to test the null that the relative elementary product prices are independent (i.e., are not cointegrated) of the average deflated group price index. Three are designed to test the null that the relative elementary is *not* independent (i.e., is cointegrated) of the average deflated price index for the group.

For each composite, we performed tests on the following elementary product price series. For the beef composite, we tested for independence between the deflated CPI (by the CPI for all food) for beef and the prices of ground chuck, ground beef, round roast, T-bone steak, and round steak. For pork, we tested for independence between the deflated CPI for pork and the prices of bacon, chops, fresh sausage, and ham. For poultry we tested for independence between the deflated CPI for poultry and the price of whole fresh chicken, chicken breast, chicken legs, and turkey. For dairy we tested for independence between the deflated CPI for dairy and the price of fresh whole milk, cheese, and ice cream. For fresh fruit we tested for independence between the deflated CPI for fresh fruit and the price of apples, bananas, grapefruit, lemons, and oranges/tangerines. For fresh vegetables we tested for independence between the deflated CPI for fresh vegetables and the price of potatoes, lettuce, tomatoes, cabbage, celery, carrots, onions, peppers, and cucumbers. Without presenting a detailed set of test results we found for each group, the tests suggested pointwise independence. Hence the tests strongly indicated that the groups form valid composites.

E. Farm Receipts Generated From At-Home Food Sales

Because we are computing retail-farm price margins for at-home commodities, it is necessary to estimate the level of farm receipts (FR) generated from a market's at-home sales. Since the proportion of consumer expenditures of food away from home has steadily increased over time (Putnam and Allshouse, 1997), it seems likely that the proportion of farm expenditures attributable to at-home food sales has also grown over time for many, if not all, of the seven product categories. However since actual farm-receipt data generated from at-home food sales are unavailable, they must be estimated econometrically. For the purposes of this study, we estimated a longrun point estimate of the proportion of farm receipts generated from at-home sales. The variable *FR* is then the product of the estimate and domestic farm receipts.

The estimates are obtained from the estimation of a market model proposed by Wohlgenant (1989) and Wohlgenant and Haidacher (1989) in which firms and products are diverse. In the reduced-form model of at-home retail and farm prices, the farm supply variable would ideally measure the farm supply allocated to at-home food production. However, the variable that has been used is total domestic farm supply (commercial disappearance). Note that if F denotes total domestic farm supply, H denotes farm supply allocated to at-home food production and A denotes farm supply allocated to away-from-home food production, then $F = H + A$ and in percent changes

$$dln\ F = \phi\ dln\ H + (1 - \phi)\ dln\ A \qquad (i)$$

where for example, $dln\ Z = dZ/Z$, and ϕ denotes the ratio of domestic farm supply used in at-home production. The idea is to compute a point estimate of ϕ for each market and use it to adjust total domestic farm receipts.

In the Wohlgenant and Wohlgenant and Haidacher framework, let p_r and p_f denote retail and farm prices and let the vector X denote the vector of marketing input prices and consumer demand shift variables. A correct specification of the model would be

$$dln\ P_r = \beta_1\ dln\ X + \beta_2\ dln\ H$$

$$(ii)$$

$$dln\ P_f = \alpha_1\ dln\ X + \alpha_2\ dln\ H$$

where the unobservable farm supply allocated to at-home industry production would be used instead of commercial disappearance (i.e., F).

If (*ii*) were observable and markets were competitive, a symmetry (price-taking) restriction and a constant returns (zero-profit) restriction would hold and could be imposed. However by solving *(i)* for *dln H* and substituting the result into *(ii)* gives the observable representation

$$dln\ P_r = \beta_1\ dln\ X + \phi^{-1}\ \beta_2\ dln\ F - \gamma\beta_2\ dln\ A \qquad (iii)$$

$$dln\ P_f = \alpha_1\ dln\ X + \phi^{-1}\alpha_2\ dln\ F - \gamma\alpha_2\ dln\ A$$

where $g = (1-f)/f$. To keep things as simple as possible, we assume *ln A* is stationary around a deterministic time trend (*T*), so that an estimable form of *(ii)* would be

$$ln\ P_r = \beta_1\ ln\ X + \phi^{-1}\ \beta_2\ ln\ F + \beta_3\ T + \varepsilon_1 \qquad (iv)$$

$$ln\ P_f = \alpha_1\ ln\ X + \phi^{-1}\alpha_2\ ln\ F + \alpha_3\ T + \varepsilon_2$$

in which ε_1, ε_2 are stationary error terms. Note that ϕ^{-1} is not identified in (*iv*). However by imposing the symmetry or constant returns restrictions we would identify ϕ^{-1} a linear specification of *(iv)*.

We estimated (*iv*) as a linear-in-parameters Seemingly Unrelated Regression model using data from 1958-97. In particular, the variables in (*iv*) are constructed in the same way as they were in a previous study (Reed and Clark, 1997). Given various combinations of restrictions that could be imposed, we chose the point estimates of ϕ^{-1} that delivered the most reasonable estimates of the proportion of farm supply allocated to at-home food production (i.e., ϕ). Finally if total domestic farm receipts is denoted as *TFR*, then farm receipts derived from at-home food sales, *FR*, is simply $FR = \phi\ TFR$. Point estimates of (1-ϕ) are: 0.514 (beef), 0.213(pork), 0.225 (poultry), 0.506 (eggs), 0.294 (dairy), 0.698 (fresh fruit), 0.155 (fresh vegetables).