Further Empirical Results

In the previous section, we argued that trends in market data reflect structural change, and found evidence of both deterministic and stochastic trends in key variables associated with seven U.S. markets. In addition, we found evidence that markets distribute these trends across consumers and food producers. Despite the claim that food markets may have undergone a sequence of permanent changes over time, we show in this section that market-clearing provides mostly stable longrun retail and farm price relationships.

The stochastic trends embedded in the variables of equations 1 require us to deviate from textbook estimation procedures. As stated above, such procedures fail to account for a non-zero correlation (at any lag) between the first difference of an explanatory variable (i.e., the fundamental error terms of the variables) and a cointegrated model's stationary error terms. This correlation is present in all but the simplest class of cointegrated models. While it does not destroy the consistency of parameter estimates, the correlation does destroy the asymptotic normality of the estimates and renders textbook formulas for the χ^2, F, and t tests invalid for inference.

Park (1990, 1992) and Park and Ogaki transform variables of cointegrated regressions based on this correlation. Their transformations reduce general, cointegrated regressions to the simple (or canonical) class of cointegrated regressions in which first differences of explanatory variables are *not* correlated with regression errors. The procedure is to first transform the variables of a cointegrated regression and then to apply textbook procedures to the transformed regressions. The canonical cointegrating regression (CCR) estimator applies OLS to a transformed single equation (Park 1990). We used the CCR estimator in the previous section to compute Park's variable addition test of the null of cointegration (Park 1992). In this section we again use the CCR estimator to compute a variable addition test of oligopsony power. In addition, we apply the seemingly unrelated regression (SUR) estimator to a transformed, seven-equation consumer demand system, and to the cointegrated quasi-reduced-form retail and farm price equations (i.e., equations 1) for each industry. This two-step estimator, termed the seemingly unrelated canonical cointegrating regression estimator (SUCCR), provides us with unbiased estimates of market structure and asymptotically-correct inference on tests of market power and constant returns in multiple equation systems (Park and Ogaki). We refer interested readers to Park, and to Park and Ogaki for details on the transformations that we use to compute the estimates presented in this section.

Consumer Demand

Kinsey and Senauer argue that changing trends in consumer behavior lead to a changing structure of the food sector. Cointegrated, market-clearing relationships would reflect the transmission of trends from consumers. To capture trends in consumer demand, we specify and estimate a consumer demand system for the seven industries. In this section, we discuss the specification of the seven-equation consumer demand system.

Appendix table 1 presents point estimates and t-values of the seven-equation system of composite per-capita demand. To construct the empirical consumer demand model, we used logged data on per-capita consumer disappearance as proxies for the seven dependent per capita consumption variables, and deflated all prices and income (explanatory variables) by the price of other nonfarm inputs (to ensure homogeneity of the market-clearing conditions). Based on Dickey-Fuller and Phillips-Perron tests, we could not refute the null that virtually all of the logged variables of the consumer demand system are unit root non-stationary around a deterministic trend. In addition, we found evidence that the individual consumer demand equations are cointegrated. Next, we imposed the symmetry and homogeneity restrictions (e.g., Deaton and Muellbauer, p. 43-46; Silberberg, p. 250-253) at the mean of the sample, and report the restricted point estimates in appendix table 1. The restricted estimates were then used to construct the demand shifters, $\ln Z_j$, for each industry j (equation 2), and to compute full reduced-form price responses reported below.[17]

[17] We are aware of the problem with incorporating the adding-up condition on this double-log specification (Deaton and Muellbauer, p. 17), and are aware of the conceptual problem of using farm-level disappearance data as the dependent variable of the system (WH). Our purpose here is to compute only approximate values of the shifters on consumer demand.

Tests of Competition and Constant Returns

Table 3 reports the χ^2 and p-values associated with symmetry, constant returns or zero profits for the industry, and the joint restrictions of symmetry and constant returns for the seven industries. Failure to refute symmetry suggests food firms take both output and farm ingredient prices as given. Failure to reject constant returns for the *industry* suggests that free entry and exit of diverse firms result in zero longrun profits. Failure to refute the joint hypotheses of symmetry and constant returns suggests that, in the long run, a 1-percent increase in the price of a farm commodity results in an increase in the price of a composite food category by a percentage equal to the cost share of the farm commodity used in producing the food category.

The symmetry (only) and constant returns (only) test results provide evidence of longrun competition. In particular, the symmetry test fails to refute (at the 0.05 level) the longrun competitive model for the beef, dairy, eggs, fresh fruit, and fresh vegetable industries. The constant returns test fails to refute the longrun competitive model for poultry, fresh fruit, and fresh vegetables. It is worth repeating that this general finding of competitive markets takes into account the many permanent changes that may have occurred in these markets over time.

Table 3 — Tests of symmetry and constant returns

	Symmetry only	Constant returns only	Symmetry and constant returns
Beef and veal	0.4773	87.9159	97.2574
	(.490)	(0.00)	(.000)
Pork	94.9740	34.3050	98.0828
	(.000)	(0.00)	(.000)
Poultry	26.1533	4.0383	39.4573
	(3E-7)	(.133)	(1E-8)
Eggs	0.0381	223.52	255.7759
	(.845)	(0.00)	(0.00)
Dairy	0.9081	48.6256	49.1519
	(.341)	(0.00)	(.000)
Fresh fruit	2.1428	4.7536	4.7871
	(.143)	(.093)	(.188)
Fresh vegetables	1.7731	0.8505	6.0862
	(.183)	(.654)	(.107)

Values are chi-square statistics. Values in parentheses are p-values, or the size of the rejection region necessary to reject the null hypothesis.

Furthermore, our tests reject the joint restriction of symmetry and constant returns for all industries except fresh fruit and fresh vegetables. The results suggest that estimates of elasticities of farm price transmission to retail apply only to markets in which final products undergo a minimal amount of food processing.

The general finding of competitive markets is consistent with WH and Wohlgenant's (1989, 1994, 1996) findings. On the one hand, we expect our findings to be similar because the model structures and data are very much the same.[18] On the other hand we expect differences because of the different estimation procedures. While our approach exploits deterministic and stochastic trends in market data, the cited works remove stochastic trends through a first-difference transformation prior to estimation. In comparing the procedures using the same retail and farm price equations, Reed and Clark find that one fails to reject parametric restrictions more often using a first-difference specification of an econometric model.[19] The reason is if the explanatory variables are integrated, a first-difference transformation removes the dominant, longrun component of the variance of the variables. Hence, if the variables are integrated, a first-difference filter would inflate the variance of parameter estimates and could reduce the likelihood of rejecting any parametric restrictions. It is noteworthy that we reject both the symmetry and the joint restriction of symmetry and constant returns more often than the cited works.

Oligopsony Power

In a previous section, we reviewed the theory used to test for oligopsony power. If food firms exert oligopsony power in acquiring farm ingredients, a gap would exist between the farm price and the value of the marginal product of farm ingredients at the market level. Shifters on the farm supply associated with the *j*th market, $\boldsymbol{S_j}$, would explain this gap. Recall from above that under the null hypothesis of food producers taking

[18] We are aware that the model specifications for eight industries in Wohlgenant (1989, 1994) include only a single nonfarm input price. The model specification for beef and pork (only) used in his 1996 paper is similar to the specification used here, as it includes the same four nonfarm input prices. Furthermore, our work uses a different deflator to impose homogeneity.

[19] The study controls for differences in the data and model specifications.

farm prices as given, no gap exists and the retail-farm price relationship is

$$(3') \quad P_{rj} = B_f^{(j)} P_{fj} + B_w^{(j)} \boldsymbol{W} + B_z^{(j)} Z_j + v_r .$$

Under the alternative of oligopsony power, the retail-farm price relationship is

$$(4') \quad P_{rj} = B_f^{(j)} P_{fj} + B_w^{(j)} \boldsymbol{W} + B_z^{(j)} Z_j + \boldsymbol{B_s^{(j)\prime} S_j} + v_r .$$

A test of whether firms acquire farm commodities competitively in national markets reduces to a test of the restriction $\boldsymbol{B_s^{(j)\prime}=0}$.

The usual chi-square tests of statistical significance of the $\boldsymbol{S_j}$ variables would be reliable only if the variables of equation 3′ and the $\boldsymbol{S_j}$ would be stationary. Because we found evidence that both sets of variables are integrated, we proceed as follows. Under the null hypothesis of price-taking, equation 3′ is cointegrated and its error terms are stationary, and the variables of equation 3′ are transformed to account for the correlation between first differences of explanatory variables and the model error terms (Park 1990, 1992). Under the null, the integrated (untransformed) $\boldsymbol{S_j}$ variables would be independent of the stationary error terms of equation 3′, and $\boldsymbol{B_s^{(j)\prime}=0}$. Under the alternative of oligopsony power, the error terms of equation 3′ would be integrated, and this price-taking relationship would be spurious. In this case, the integrated $\boldsymbol{S_j}$ variables and the integrated error terms of equation 3 would not be independent and in general $\boldsymbol{B_s^{(j)\prime} \neq 0}$. Rather than testing for the statistical significance of $\boldsymbol{S_j}$, chi-square tests of $\boldsymbol{B_s^{(j)\prime}=0}$ represent a test of whether the price taking model is cointegrated or correctly specified against the alternative that the oligopsony power relationship is correctly specified (Park 1992).

Table 4 reports the chi-square and p-values computed from the transformed regressions. The results report the statistics associated with one integrated, industry-specific farm supply shifter (S_1) and both integrated, industry-specific farm supply shifters (S_1 & S_2).[20] The results are based on a specification that includes a constant and a deterministic time trend. At reasonable levels of rejection, we fail to reject the null that in national markets, the seven food industries acquire farm ingredients competitively.

[20] The industry-specific shift variables on farm supply are defined in the appendix. For the test to be meaningful, the variables must be integrated. We could not refute the claim of integrated farm supply shifters. Furthermore, because the null hypothesis is that equation 3′ (and not equation 4′) is cointegrated, the $\boldsymbol{S_j}$ variables are not transformed.

Table 4 — Tests of competition in acquiring farm commodities

	S_1	S_1 & S_2
Beef and veal	1.2377 (.266)	1.3832 (.501)
Pork	0.0443 (.833)	2.4686 (.291)
Poultry	0.0538 (.816)	0.2956 (.862)
Eggs**	0.1994 (.655)	
Dairy	0.1294 (.719)	0.2022 (.904)
Fresh fruit	2.5509 (.110)	
Fresh vegetables	0.2176 (.641)	

Entries are χ^2 values and values in parentheses are significance levels. The sets of supply shifters on farm supply are as follows (see Appendix for data series definitions): Beef: S_1 is steers, S_1 & S_2 are steers and corn price; Pork: S_1 is hog inventories, S_1 & S_2 are hog inventories and corn price; Poultry: S_1 is the price of soybean meal, S_1 & S_2 are the price of soybean meal and corn price; Eggs: S_1 is laying flock; Dairy: S_1 is cow numbers and S_1 & S_2 are cow numbers and price of soybean meal; Fresh fruit: S_1 is farm wages; Fresh vegetables: S_1 is farm wages.

**Sample interval is 1960-97.

Longrun Industry Structure

Table 5 presents SUCCR estimates of the parameters of equations 1 for the seven food markets. Although they account for a negative own-price consumer response, they are conditioned on shifters of consumer demand (i.e., *ln Z*). Hence, the estimates would not account for particular shifts in consumer demand induced by endogenous changes in relative retail prices among the seven composite markets. However, by controlling for such shifts, the ‘quasi’ reduced-form estimates of equations 1 provide information on industry structure. Given evidence of permanent change and cointegration presented above, the results in table 5 represent longrun estimates of industry structure.

Theory predicts a negatively sloped, longrun industry demand for farm ingredients. In terms of equations 1,

Table 5 — Quasi-reduced-form estimates

Variable	Beef and veal*		Pork**		Poultry**		Eggs*		Dairy*		Fresh fruit*		Fresh vegetables*	
	Retail price	Farm price	Retail price	Farm price	Retail price	Farm price	Retail price	Farm price	Retail price	Farm price	Retail price	Farm price	Retail price	Farm price
Demand shifter (*Z*)	1.011	2.537	1.075	1.020	0.808	0.706	4.285	1.045	1.132	1.055	0.062	0.447	0.039	1.096
	(11.1)	(18.5)	(13.6)	(4.53)	(7.72)	(7.13)	(17.5)	(7.95)	(15.7)	(8.15)	(.32)	(1.71)	(.21)	(5.87)
Wage (W_1)	1.372	1.377	0.013	2.236	-0.461	1.229	0.079	2.037	0.172	1.792	-0.930	1.577	-0.115	1.746
	(15.6)	(5.38)	(.197)	(10.6)	(-2.99)	(4.85)	(.36)	(7.91)	(3.26)	(14.9)	(-5.1)	(3.92)	(-.90)	(6.86)
Packaging price (W_2)	0.446	0.354	0.115	-0.013	0.000	0.005	1.395	-0.080	0.010	-0.010	0.491	-0.108	0.308	0.235
	(6.29)	(1.69)	(1.63)	(-.06)	(.001)	(.017)	(5.48)	(-.29)	(.21)	(-.09)	(2.64)	(-.34)	(2.24)	(1.08)
Transportation price (W_3)	-0.608	-0.534	-0.123	-0.795	0.441	-0.261	-0.966	-1.362	-0.235	-0.468	0.224	-0.015	0.191	-0.251
	(-7.77)	(-2.27)	(-2.05)	(-3.84)	(2.90)	(-1.01)	(-4.03)	(-5.03)	(-4.82)	(-3.91)	(1.36)	(.04)	(1.52)	(-.98)
Energy price (W_4)	-0.157	-0.170	0.009	-0.100	-0.132	-0.101	-0.021	0.146	0.037	-0.152	-0.131	-0.224	-0.282	-0.255
	(-4.09)	(-1.48)	(.25)	(-.84)	(-1.47)	(-.69)	(-.15)	(.93)	(1.43)	(-2.55)	(-1.36)	(-1.31)	(-3.97)	(-2.09)
Farm supply (F_i)	-1.446	-1.970	-1.187	-2.107	-1.057	-0.897	-0.658	-2.125	-0.517	-1.593	-0.148	-0.984	-0.373	-1.342
	(-18.5)	(-8.72)	(-22.4)	(-17.2)	(-8.17)	(-9.69)	(-7.95)	(-21.9)	(-8.15)	(-15.3)	(-1.71)	(-3.72)	(-5.87)	(-7.96)
Constant	3.690	-0.096	0.257	8.223	7.300	2.551	-20.356	8.317	-0.999	4.941	0.593	4.318	2.924	3.210
	(9.83)	(-.11)	(.64)	(8.49)	(6.63)	(3.38)	(-13.5)	(14.4)	(-1.21)	(8.49)	(-.50)	(2.07)	(3.22)	(2.55)
Time trend	-0.004	-0.025	-0.000	-0.018	0.006	-0.020	-0.016	-0.023	-0.005	-0.018	0.021	-0.017	0.021	-0.018
	(-4.48)	(-10.1)	(-0.33)	(-7.27)	(1.01)	(-6.59)	(-5.28)	(-6.96)	(-6.70)	(-14.2)	(-4.33)	(-4.34)	(4.79)	(-7.01)

* Symmetry imposed.
**Unrestricted estimates.

theory predicts $A_{ff} < 0$. The negative estimates of A_{ff} for each of the seven markets are statistically different from zero. The estimates describe downward sloping, industry-level demand schedules for farm ingredients.

The theory of diverse firms in a competitive market predicts that positive shifts in the consumer demand function trace an upward sloping, longrun industry supply schedule. In terms of equations 1, theory predicts $A_{rz} > 0$. The estimates of A_{rz} are positive for all seven markets, and except for fresh fruit and fresh vegetables, they are statistically different from zero at reasonable levels of rejection.

The theory of competitive markets predicts that if farm ingredients are normal factors of production, a contraction in farm supply raises consumer food prices. In terms of equations 1, theory predicts $A_{rf} < 0$. The estimates of A_{rf} are negative for each of the seven industries, and are statistically different from zero. Theory also predicts that if farm ingredients are normal, $A_{fz} > 0$. The estimates of A_{fz} are positive for all seven markets and are statistically different from zero. Negative estimates of A_{rf} and positive estimates of A_{fz} suggest the aggregate farm ingredients are normal factors of industry production.

The estimates presented in table 5 suggest some marketing factors are inferior to a number of industries. Negative signs on elements of $\boldsymbol{A_{rw}}$ suggest the particular factor is inferior and that the supply response of inframarginal firms exceeds that of marginal firms. For example, the results suggest transportation is an inferior factor for the beef and pork industries. The estimates may indicate that for the U.S. pork industry, changes in vertical coordination have allowed the inframarginal firms in the Southeast United States to economize on the transportation of hogs. The estimates also suggest that labor is an inferior factor for the fresh fruit and fresh vegetable industries.

The results presented in table 5 also point to some nonfarm inputs that appear to be normal across industries. The positive signs on the A_{rw} coefficients associated with the price of packaging suggest that packaging is a normal factor for all seven industries. This may reflect the notion that consumers value the convenience associated with the packaging of food products, and suggests that consumers would be willing to pay more for packaging through higher food prices. Furthermore, labor appears to be a normal factor of production for four of the seven industries.

Input Substitution

The variety of consumer products and diversity of firms within a composite industry (e.g., fresh fruits) provide evidence of variable-proportions at the market level (e.g., WH, Wohlgenant [1999]). Refutation of restrictions implied by fixed-proportions analyses provides additional evidence.

The diversity of a composite industry's products suggests that production processes vary across firms. Meat products, for example, vary by the amount of processing. Manufacturers of processed meat products would, for example, utilize higher proportions of nonfarm ingredients (e.g., packaging, energy) than manufacturers of fresh meat products. An increase in the price of nonfarm inputs relative to farm inputs would, therefore, raise longrun average and marginal costs for manufacturers of processed products more than for manufacturers of fresh products.[21] In terms of meat industry supply, the quantity of manufactured products would fall relative to fresh products. In terms of input demand, the reduction in the supply of manufactured products relative to fresh products means that the ratio of nonfarm inputs to farm inputs demanded by the industry falls in response to an increase in the relative price of nonfarm inputs.

WH (p. 21) formally show that if firms are diverse, an industry's input price response can be decomposed into a substitution and an output effect in precisely the same manner as one could decompose the response of a single firm with a variable proportions production technology. Wohlgenant (1999) illustrates the presence of input substitution directly for a composite industry producing heterogeneous final food products. All that is required is that production functions differ across firms. These results imply that even if each firm in an industry produces its specific product in fixed-input proportions, if these proportions vary across firms, variable-proportions relationships apply at the market level.

Test results presented in table 6 suggest that market data do not follow the predictions of fixed proportions. In particular, fixed proportions at the market level imply that the own-price elasticity of an industry's

[21] The marginal costs could fall if nonfarm ingredients are inferior factors of industry production. The discussion here assumes they are normal factors.

Table 6 — Tests of fixed-proportions production

Industry	t-values
Beef and veal	110.744
Pork	15.063
Poultry	25.204
Eggs	233.344
Dairy	4.806
Fresh fruit	51.317
Fresh vegetables	-331.354

Values are Student t-values designed to test the restriction that the parameter A_{ff} equals the inverse of the demand for farm ingredients implied by fixed proportions. Values approximately equal to 2 (in magnitude) would reject the null of fixed proportions at the 0.05 level. The estimates of A_{ff} are found in table 5, and the estimates of the standard errors are the estimates used to compute the t-values in table 5. Point estimates of the own-price elasticities of consumer demand and the farm share for each market are found in appendix tables 1 and 2.

demand for farm ingredients equals the product of the own-price elasticity of consumer demand and the industry's cost share of farm ingredients (e.g., George and King). Since $A_{ff}^{(j)}$ is the inverse of the industry *j*'s demand elasticity with respect to the *j*th farm price (from equations 1), e_{jj} is the own-price elasticity of consumer demand for the *j*th consumer product, and $S_f^{(j)}$ is the industry's cost share of farm ingredients, the restriction $A_{ff}^{(j)} = 1/(S_f^{(j)} e_{jj})$ would hold if an industry produced its composite mix of products in fixed-factor proportions. Based on the t-values reported in table 6, one can refute the null hypothesis of fixed proportions at the industry level for reasonable levels of rejection.[22]

Estimates of elasticities of input substitution can be computed from model parameters (Wohlgenant 1996) and used to measure the ease with which an industry varies its factor proportions. Table 7 reports estimates of Morishima elasticities of substitution (Blackorby and Russell) between the farm and the four marketing inputs when (in this case) changes in the farm-to-nonfarm price ratio are caused specifically by a change in the farm price.[23] The larger the magnitude of the estimate, the easier it is for an industry to vary ratios of farm and marketing inputs. Positive estimates suggest the input pairs are substitutes (when the farm price changes), and negative estimates suggest they are complements. For example, the results in table 7 suggest that as farm prices rise, labor and packaging substitute for the farm ingredient in all seven industries. As in Wohlgenant (1996), the estimates suggest that significant substitution possibilities exist in U.S. food production.

Table 7 — Morishima elasticities of substitution

Industry	Nonfarm inputs			
	Labor	Packaging	Transport	Energy
Beef and veal	2.613	1.910	-3.084	-1.775
Pork	1.717	0.456	-1.470	-0.013
Poultry	4.356	1.146	-1.912	-1.220
Eggs	4.181	0.092	-10.45	2.807
Dairy	3.083	0.590	-2.193	-1.210
Fresh fruit	2.811	0.697	0.939	-1.227
Fresh vegetables	2.270	1.275	-0.218	-1.212

Full-Reduced-Form Price Responses

Table 8 reports full-reduced-form estimates of percent changes in retail and farm prices induced by a 1-percent increase in the set of explanatory variables. Unlike the quasi-reduced-form estimates (table 5), the full-reduced-form estimates account for the effect of endogenous shifts in consumer demand when relative retail prices change. For example, increased wages may increase the retail price of both beef and pork products, but the magnitude of the responses would differ in the markets. The results presented in table 8 capture the effect of consumer responses to changes in relative retail prices on retail and farm prices.[24]

[22] The results are similar to those reported by Wohlgenant (1996). The tests are preliminary because they treat the estimate of the own-price elasticity of consumer demand as a parameter with no variation. A simulation procedure suggested by Ng, or a bootstrap procedure suggested by Li and Maddala may provide a more precise test.

[23] Since Morishima elasticities of substitution are not symmetric, an estimate of response caused by a 1-percent change in the factor price ratio induced by a change in the nonfarm input price would differ from the estimates reported in table 7.

[24] The full-reduced-form estimates are computed using equations 19a and 19b (Wohlgenant 1991) or equations 30a and 30b (WH). Whereas theory provides expected signs on the coefficients of the quasi-reduced form, it does not provide expected signs on the parameter estimates of the full-reduced form. Technically, the reason is that unlike a single consumer demand equation, a system of consumer demand equations is not negative definite (Chavas and Cox). This is essentially why the quasi-reduced form can provide information on industry structure and the full-reduced form cannot.

Table 8 — Full-reduced-form estimates

Explanatory variable	Beef and veal Retail price	Beef and veal Farm price	Beef and veal Spread	Pork Retail price	Pork Farm price	Pork Spread	Poultry Retail price	Poultry Farm price	Poultry Spread
	Percent change								
Nonfood price	0.707	1.773	-1.066	0.749	0.711	0.038	-0.765	-0.669	-0.096
Beverage price	-0.138	-0.347	0.209	0.098	0.093	0.005	0.149	0.130	0.019
Sugar price	0.379	0.952	-0.572	-0.164	-0.155	-0.008	-0.788	-0.689	-0.099
Cereal price	-0.861	-2.160	1.299	-0.177	-0.168	-0.009	1.073	0.938	0.135
Income/capita	-0.043	-0.107	0.065	-0.221	-0.209	-0.011	0.604	0.528	0.076
Population	2.294	5.755	-3.461	2.736	2.596	0.140	0.970	0.848	0.122
Wage	2.292	3.684	-1.392	1.586	3.729	-2.143	-1.220	0.566	-1.786
Package price	0.592	0.721	-0.129	0.483	0.336	0.147	0.134	0.122	0.012
Transport price	-1.150	-1.893	0.743	-0.940	-1.570	0.631	0.687	-0.046	0.733
Energy price	-0.117	-0.069	-0.048	-0.039	-0.146	0.107	-0.179	-0.141	-0.038
Cattle supply	-2.037	-3.452	1.416	-1.329	-1.261	-0.068	0.477	0.417	0.060
Hog supply	-0. 577	-1.448	0.871	-1.577	-2.477	0.900	0.186	0.163	0.023
Poultry supply	0.096	0.240	-0.144	0.079	0.075	0.004	-1.159	-0.986	-0.173
Egg supply	-0.046	-0.116	0.070	-0.040	-0.038	-0.002	-0.041	-0.036	-0.005
Milk supply	-0.065	-0.163	0.098	-0.091	-0.086	-0.005	-0.133	-0.116	-0.017
Fruit supply	0.042	0.105	-0.063	0.035	0.033	0.002	-0.046	-0.040	-0.006
Veg. supply	0.063	0.157	-0.095	0.062	0.058	0.003	-0.068	-0.060	-0.009

Explanatory variable	Eggs Retail price	Eggs Farm price	Eggs Spread	Dairy Retail price	Dairy Farm price	Dairy Spread	Fresh Fruit Retail price	Fresh Fruit Farm price	Fresh Fruit Spread
	Percent change								
Nonfood price	2.477	0.604	1.873	1.143	1.065	0.078	-0.074	-0.535	0.460
Beverage price	0.054	0.013	0.041	0.138	0.129	0.009	0.019	0.138	-0.119
Sugar price	-0.915	-0.223	-0.692	-0.217	-0.202	-0.015	-0.052	-0.374	0.322
Cereal price	-0.801	-0.195	-0.606	0.270	0.251	0.018	0.111	0.796	-0.685
Income/capita	-1.449	-0.353	-1.096	-0.482	-0.449	-0.033	0.039	0.278	-0.239
Population	7.627	1.860	5.767	1.958	1.824	0.134	-0.084	-0.604	0.520
Wage	2.252	2.567	-0.315	0.496	2.093	-1.597	-1.073	0.547	-1.620
Packaging price	1.898	0.042	1.856	0.166	0.135	0.031	0.457	-0.350	0.808
Transport price	-2.010	-1.617	-0.394	-0.418	-0.639	0.221	0.307	0.576	-0.269
Energy price	-0.159	0.112	-0.271	0.001	-0.186	0.186	-0.131	-0.226	0.095
Cattle supply	-1.799	-0.439	-1.361	-0.314	-0.292	-0.021	0.110	0.794	-0.683
Hog supply	-0.680	-0.166	-0.514	-0.182	-0.170	-0.012	0.041	0.291	-0.251
Poultry supply	-0.407	-0.099	-0.308	-0.143	-0.134	-0.010	-0.026	-0.187	0.161
Egg supply	-0.733	-2.143	1.410	-0.038	-0.035	-0.003	0.006	0.043	-0.037
Milk supply	-0.321	-0.078	-0.243	-0.558	-1.632	1.074	0.007	0.050	-0.043
Fruit supply	0.082	0.020	0.062	0.011	0.010	0.001	-0.151	-1.009	0.858
Veg. supply	0.013	0.003	0.010	0.005	0.005	0.000	-0.007	-0.050	0.043

Explanatory variable	Fresh Vegetables Retail price	Fresh Vegetables Farm price	Fresh Vegetables Spread
	Percent change		
Nonfood price	-0.043	-1.197	1.155
Beverage price	0.005	0.151	-0.146
Sugar price	-0.023	-0.643	0.620
Cereal price	0.048	1.339	-1.291
Income/capita	0.021	0.589	-0.568
Population	-0.011	-0.319	0.307
Wage	-0.182	-0.146	0.037
Packaging price	0.298	-0.037	0.336
Transport price	0.224	0.698	-0.473
Energy price	-0.282	-0.249	-0.033
Cattle supply	0.050	1.404	-1.354
Hog supply	0.022	0.612	-0.590
Poultry supply	-0.012	-0.331	0.319
Egg supply	0.000	0.013	-0.012
Milk supply	0.001	0.037	-0.035
Fruit supply	-0.002	-0.060	0.058
Veg. supply	-0.375	-1.401	1.027

The effect of consumer substitution links the effects of changes in farm supply on retail and farm prices across the seven markets. For example, the first panel of table 8 suggests that increases in cattle supply depress both retail and farm prices for pork. Hence, increased cattle supply will lower both cattle prices (farm-level price) and consumer-level beef prices. Because our estimates suggest that consumers treat beef and pork as gross substitutes (appendix table 1), lower relative beef prices imply a reduction in consumer demand for pork. Because hogs are a normal factor of production in pork supply, hog prices (farm level) also fall. In this particular example, it is important to recall that estimates presented in table 8 exclude the effects of imports and exports of farm commodities.[25]

The column labeled "spread" summarizes the relative responses of retail and farm prices associated with a 1-percent increase in a particular explanatory variable. In particular, the estimates, computed in this double-log specification as the difference between the percent change in the retail and the percent change in the farm price, represent Gardner's response estimates of retail-to-farm price spreads. A positive (negative) sign implies that the market's retail price response exceeds (is less than) the response of the market's farm price. Because the estimates account for the response of a market's farm price and not the *retail equivalent* farm price based on variable proportions, the "spread" estimates reported in table 8 represent responses of spreads computed under the assumption of fixed-factor proportions.

Table 9 — Own-price elasticities of farm and consumer demand

Market	Own-farm price elasticity of industry demand for farm ingredients	Own-retail price elasticity of consumer demand
Beef and veal	-0.402	-0.065
Pork	-0.514	-0.745
Poultry	-1.074	-0.607
Eggs	-0.472	-0.064
Dairy	-0.627	-0.974
Fresh fruit	-1.020	-0.208
Fresh vegetables	-0.753	0.054

Table 9 compares the own-price elasticities of consumer demand with the full-reduced form, own-price elasticity of farm demand for farm ingredients for each market. Fixed-proportions production implies that an industry's input demand would be less own-price elastic than the own-price elasticity of retail demand. However, the results in table 9 suggest that for four of the seven markets, the industry's full-reduced-form demand for farm ingredients is more own-price elastic than consumer demand.[26] Such results call into question the validity of market price analyses based on fixed proportions.

[25] Attempts to interpret the results presented in this section are difficult because standard errors and t-tests are not computed. Such estimates might be computed using the methods suggested in footnote 22.

[26] The derived demand for farm ingredients reported in table 9 is as follows. If the full-reduced-form system (i.e., table 8) of farm price equations is represented in matrix notation as $\boldsymbol{P_f} = \boldsymbol{\beta_1} \boldsymbol{F} + \boldsymbol{\beta_2} \boldsymbol{X}$, where $\boldsymbol{F}$ is the vector of farm supplies, and $\boldsymbol{X}$ is the vector of all other explanatory variables, the estimates in table 9 are $\boldsymbol{\beta_1^{-1}}$. The own-price elasticities of derived demand for farm ingredients (accounting for consumer substitution) are the diagonal elements of $\boldsymbol{\beta_1^{-1}}$.