Price transmission effects through three stages of food production

An analysis of price transmission through three stages of food production reveals substantial differences in price transmission from producer food to consumer food consumed at home versus that consumed away from home; increases in various food-related PPIs lead to increases in the CPI for food consumed at home but not the CPI for food consumed away from home

Jonathan C. Weinhagen

Jonathan C. Weinhagen is an economist in the Division of Producer Price Indexes, Bureau of Labor Statistics. Email: weinhagen.jonathan@bls.gov.

According to the Consumer Expenditure Survey (CE) of the Bureau of Labor Statistics, U.S. consumers spent $6,129, on average, on food in 2010, accounting for close to 13 percent of average household annual expenditures. Of total household food expenditures, approximately 60 percent ($3,624) was spent on food consumed at home and 40 percent ($2,505) was spent on food consumed away from home. The CE defines food consumed at home as food purchased from grocery stores or other food stores. The CE defines food consumed away from home as meals (including take-out) purchased from restaurants, vending machines, and mobile vendors.

Given the relatively large share of household spending made up by food, changes in food prices can affect consumer welfare substantially. Over the past decade, prices for unprocessed foods have risen considerably. From December 2001 to May 2011, the Producer Price Index (PPI) for unprocessed foodstuffs and feedstuffs (also known as the PPI for crude foodstuffs and feedstuffs) increased approximately 90 percent. This article uses econometric techniques to examine price transmission through three stages of food production: unprocessed producer foods, finished producer food that eventually will be sold to consumers, and consumer food. The article analyzes price transmission effects on consumer food, not only overall, but also separately for that expenditure category's two components: food consumed at home and food consumed away from home. Analysts expect that price transmission from producer food to food consumed at home differs from price transmission from producer food to food consumed away from home, because the service of preparing food may represent a substantial component of the value of food consumed away from home.

The article begins by using a vector autoregression (VAR) model to analyze price transmission from producer food to total consumer food. Then, in the next section, two separate VAR models are used to examine whether there are differences in price transmission from producer food to consumer food purchased for home consumption as opposed to consumer food consumed away from home. Finally, conclusions drawn from the analysis are presented.

Producer food to total CPI food

VAR models can be used to examine the causal relationships between food prices at three stages of food production. VAR modeling involves estimating a series of equations in which each variable is expressed as a linear combination of itself and all other variables in the system.[1] A three-variable VAR model (henceforth referred to as VAR-TOTAL because it includes total food) using the PPI for unprocessed foodstuffs and feedstuffs, the PPI for finished consumer food, and the Consumer Price Index (CPI) for total food was estimated with monthly data from January 1980 through May 2011. The PPI for unprocessed foodstuffs and feedstuffs measures price changes in unprocessed foods and feeds sold to businesses as inputs to production. The PPI for finished consumer food measures price changes received by manufacturers of both processed and unprocessed food that will eventually be sold to consumers. The CPI for total food measures the average change in the selling price that consumers pay for food and includes both food consumed at home and food consumed away from home.

All data used in this article were seasonally adjusted and converted to percentage-growth form by taking the first differences of their natural logarithms. Converting time-series data to percentage-growth form typically induces stationarity in the data. A time series is stationary if the mean, variance, and covariance of the series are not dependent on time. Using nonstationary time series to estimate a VAR model invalidates conventional significance tests of the model's coefficients and can treat insignificant correlations as significant, even if both variables follow mostly independent trends. Dickey–Fuller tests were used to determine whether the series, expressed in percentage-growth terms, were stationary.[2] The tests included trends, intercepts, and sufficient lags to ensure white-noise residuals. The tests indicated that all of the time series used were stationary when expressed in percentage-growth terms. To determine the correct lag structure of the VAR, the Schwarz information criterion was implemented.[3] The criterion suggested that a VAR whose equations have one lag is optimal; therefore, one lag of each variable was used to estimate the VAR.

The VAR model was first used to test for Granger causality among the indexes. A variable is said to Granger-cause a second variable when adding past values of the variable to an autoregressive model of the second variable improves the predictability of the latter. Wald statistics were used to test the null hypothesis that there was no Granger causality. Wald tests are based on measuring the extent to which the unrestricted estimates fail to satisfy the restrictions of the null hypothesis.[4] A small p-value of the Wald statistic rejects the null hypothesis that there is no feedback to the dependent variable, and a large p-value of the Wald statistic implies that the null hypothesis is not rejected. A p-value of less than 0.01 indicates rejection of the null hypothesis at the 99-percent confidence level, whereas a p-value of 0.05 or less indicates rejection of the null hypothesis at the 95-percent confidence level. A p-value greater than 0.05 suggests acceptance of the null hypothesis that there is no Granger causality.

In addition to testing for Granger causality from individual indexes to the dependent variable, the analysis tested the joint lagged values of variables at stages of processing before and after the dependent variable for Granger causality. For example, the null hypothesis that prices for unprocessed foods and feeds and for finished consumer food do not jointly Granger-cause the CPI for total food was tested. Table 1 presents the results of the Granger causality tests.

The tests indicate that food prices at earlier stages of production generally Granger-cause food prices at more processed stages of production but that food prices at later stages of production do not Granger-cause food prices

Table 1. Results of the Granger causality tests

VAR-TOTAL: Null hypothesis	Chi-square	p-value
Dependent variable: PPI for unprocessed foodstuffs and feedstuffs		
PPI for finished consumer food = 0	0.070	0.791
CPI for total food = 0	2.083	.149
PPI for finished consumer foods/CPI for total food = 0	2.911	.233
Dependent variable: PPI for finished consumer food		
PPI for unprocessed foodstuffs and feedstuffs = 0	25.109	.000
CPI for total food = 0	1.012	.315
Dependent variable: CPI for total food		
PPI for unprocessed foodstuffs and feedstuffs = 0	.354	.552
PPI for finished consumer food = 0	23.308	.000
PPI for unprocessed foodstuffs and feedstuffs/PPI for finished consumer food = 0	46.092	.000

at earlier stages of production. The tests show that the PPI for unprocessed foodstuffs and feedstuffs Granger-causes the PPI for finished consumer food, the PPI for finished consumer food Granger-causes the CPI for total food, and the PPI for unprocessed foodstuffs and feedstuffs and the PPI for finished consumer food jointly Granger-cause the CPI for total food. By contrast, the CPI for total food does not Granger-cause the PPI for finished consumer food, the CPI for total food does not Granger-cause the PPI for unprocessed foodstuffs and feedstuffs, the PPI for finished consumer food does not Granger-cause the PPI for unprocessed foodstuffs and feedstuffs, and the CPI for total food and the PPI for finished consumer food do not jointly Granger-cause the PPI for unprocessed foodstuffs and feedstuffs.

VAR coefficients are difficult to interpret because of the multivariate nature of the models. Accordingly, impulse response functions and variance decompositions were developed to assist in interpreting VARs. Impulse response functions measure the effect of a one-standard-deviation perturbation of a variable in a system of equations on current and future values of all variables in the system. Variance decompositions show the percentage of forecast error variance in one variable of the VAR that is explained by perturbations to all variables used in the VAR.[5] Because shocks within a VAR are generally not contemporaneously independent of each other, a random shock to one variable often occurs simultaneously with shocks to other variables. To overcome this problem, the residuals may be orthogonalized by a Cholesky decomposition in which the covariance matrix of the residuals is lower triangular. Therefore, a shock to one variable in the system contemporaneously affects only variables ordered after that variable in the VAR.[6]

The residuals of the VAR were orthogonalized by a Cholesky decomposition using the following ordering: PPI for unprocessed foodstuffs and feedstuffs, PPI for finished consumer food, and CPI for total food. This ordering was chosen because unprocessed foods and feeds are used as inputs to produce finished consumer foods, which are then used as inputs to CPI food. In addition, the Wald tests that were carried out indicated that the PPI for unprocessed foodstuffs and feedstuffs Granger-causes the PPI for finished consumer food and that the PPI for finished consumer food Granger-causes the CPI for food. Subsequent to orthogonalization of the residuals, impulse response functions and variance decompositions were constructed from the VAR coefficients.

Chart 1 presents the accumulated impulse response functions of one-standard-deviation shocks to the three variables in the system. Standard error bands (dashed red lines) were constructed with the use of the software program EVIEWS 5.0 to represent the statistical significance of the impulse response functions. The impulse responses were found to be significant at the 95-percent confidence level when both standard error bands were simultaneously above or below zero on the *y*-axis.

The impulse response functions show that changes in prices are passed forward through the three stages of food production. In all cases, price shocks at earlier stages of food production lead to statistically significant changes in prices at later stages of food production. For example, a one-standard-deviation (2.4-percent) unanticipated increase in the PPI for unprocessed foodstuffs and feedstuffs leads to a 0.7-percent increase in the PPI for finished consumer food. More than half of the impact of the unprocessed-food shock on the PPI for finished consumer food occurs in the same month as the shock, and the full impact is reached after 4 months. A one-standard-deviation (2.4-percent) unanticipated increase in the PPI for unprocessed foodstuffs and feedstuffs leads to a 0.17-percent increase in the CPI for total food. Approximately a quarter of the impact of the unprocessed-food shock occurs in the same month as the shock, and the full impact is reached after 6 months. Likewise, a one-standard-deviation (0.58-percent) increase in the PPI for finished consumer food results in a 0.21-percent rise in the CPI for total food. By contrast, the impulse response functions do not suggest that price changes are passed backward through the stages of food production: in no instances does an unanticipated change to an index at a later stage of food production lead to a statistically significant change to an index at an earlier stage of food production.

Table 2 presents the variance decompositions for the stage-of-processing food indexes after 12 months. Like the impulse response functions, the variance decompositions imply that price shocks are passed forward, and not backward, through the stages of food production.

Table 2 shows that 11.35 percent of the forecast error variance in the CPI for total food can be attributed to shocks to the PPI for unprocessed foodstuffs and feedstuffs while 23.93 percent is attributable to finished consumer food. Alternatively, less than 0.5 percent of the forecast error variance in the PPIs for unprocessed foodstuffs and feedstuffs and for finished consumer food can be explained by shocks to CPI food.

In sum, the Granger causality tests, impulse response functions, and variance decompositions all indicate that changes in producer prices for unprocessed foods and feeds, as well as changes in producer prices for finished consumer food, are transmitted forward to prices for

Chart 1. Accumulated impulse response functions from VAR-TOTAL

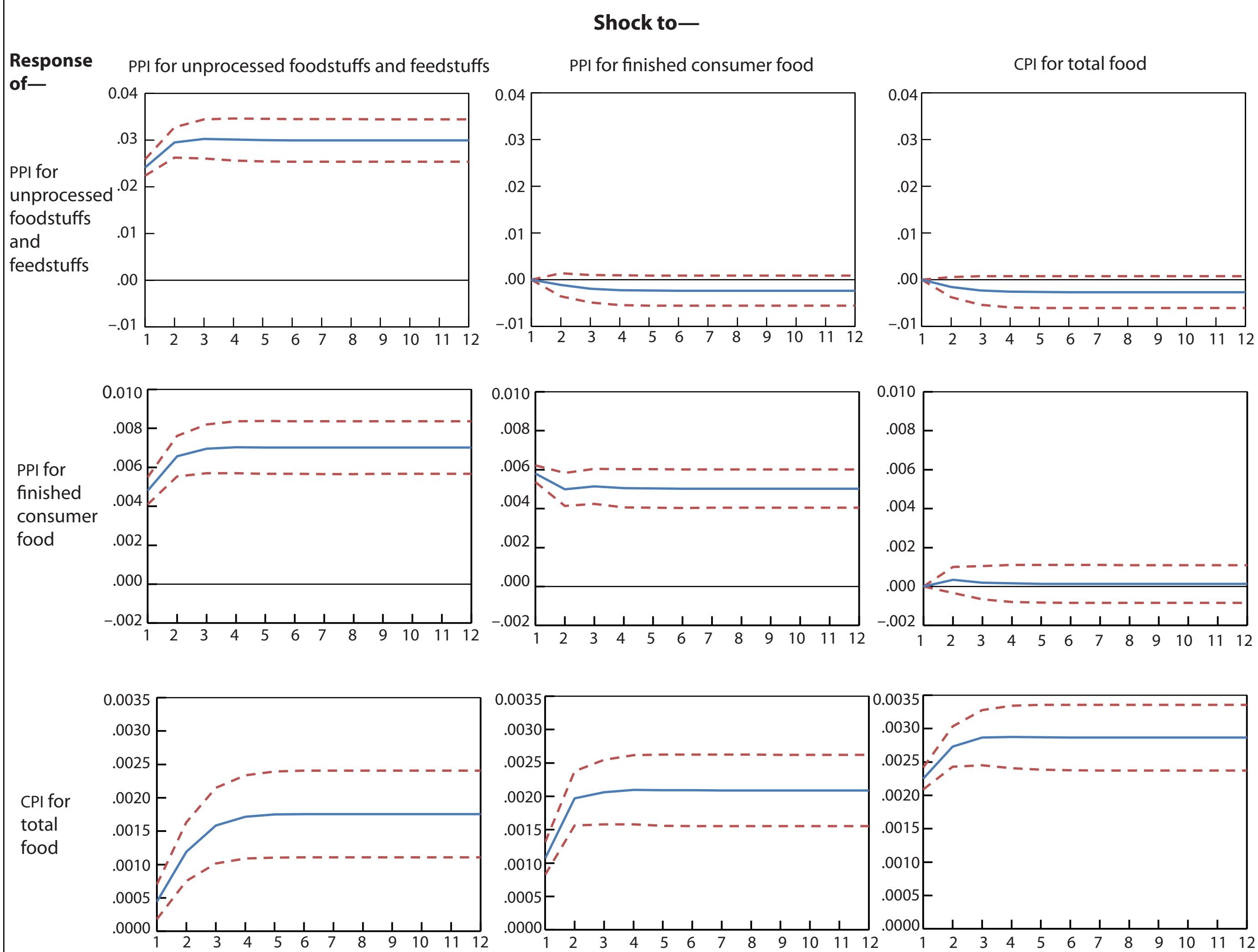


Table 2. Variance decompositions from VAR-TOTAL after 12 months

Decomposition variable	Percentage of forecast error due to—		
	PPI for unprocessed foodstuffs and feedstuffs	PPI for finished consumer food	CPI for total food
PPI for unprocessed foodstuffs and feedstuffs	99.18	0.32	0.49
PPI for finished consumer food	43.30	56.47	.23
CPI for total food	11.35	23.93	64.72

consumer food. The tests also suggest that price changes for foods are not passed backward through the stages of food production.

Producer food to CPI food consumed at home and away from home

This section uses two separate VAR models to examine whether there are differences in price transmission from producer food to consumer food purchased for home consumption versus consumer food consumed away from home. The first VAR, composed of the PPI for unprocessed foodstuffs and feedstuffs, the PPI for finished consumer food, and the CPI for food consumed at home, will be referred to as VAR-HOME. The second VAR, composed of the PPI for unprocessed foodstuffs and feedstuffs, the PPI for finished consumer food, and the CPI for food consumed away from home, will be referred to as VAR-AWAY.[7] Estimating two separate VARs—one that includes the CPI for food consumed at home as the final stage and the other that instead includes the CPI for food consumed away from home as the final stage—allows for a separate examination of price transmission effects on food consumed at home versus food consumed away from home. As mentioned earlier, it might be expected that the price transmission effects from producer food to consumer food consumed away from home would be less than those to consumer food consumed at home, because the former includes the service of food preparation as a substantial component.

One lag of monthly seasonally adjusted data from January 1980 through May 2011 was used to estimate the two VARs. All data were seasonally adjusted and converted to percentage-growth form by taking first differences of their natural logarithms. Dickey–Fuller tests that were run indicated that all series expressed in percentage-growth form were stationary. The VAR models were used to examine Granger causality among prices at the three stages of production. Table 3 displays the results of the Granger causality tests.

The results of the Granger causality tests developed from VAR-HOME and VAR-AWAY are similar to each other and to those from VAR-TOTAL, which includes total foods. For both VAR-HOME and VAR-AWAY, Granger causality occurs only from indexes at earlier stages of food production to those at later stages of food production. The Granger causality tests, therefore, do not provide strong evidence of differences in price pass-through from producer food prices to consumer food prices for food

Table 3. Results of the Granger causality tests

Variables	Chi-square	*p*-value
VAR-HOME: Null hypothesis		
Dependent variable: PPI for unprocessed foodstuffs and feedstuffs Independent variable:		
PPI for finished consumer food = 0	0.109	0.742
CPI for food at home = 0	1.525	.217
PPI for finished consumer food/CPI for food at home = 0	2.351	.309
Dependent variable: PPI for finished consumer food Independent variable:		
PPI for unprocessed foodstuffs and feedstuffs = 0	24.588	.000
CPI for food at home = 0	.388	.534
Dependent variable: CPI for food at home Independent variable:		
PPI for unprocessed foodstuffs and feedstuffs = 0	.962	.327
PPI for finished consumer food = 0	28.884	.000
PPI for unprocessed foodstuffs and feedstuffs/PPI for finished consumer food = 0	60.369	.000
VAR-AWAY: Null hypothesis		
Dependent variable: PPI for unprocessed foodstuffs and feedstuffs Independent variable:		
PPI for finished consumer food = 0	.542	.462
CPI for food away from home = 0	2.120	.145
PPI for finished consumer food/CPI for food away from home = 0	2.948	.229
Dependent variable: PPI for finished consumer food Independent variable:		
PPI for unprocessed foodstuffs and feedstuffs = 0	26.121	.000
CPI for food away from home = 0	2.515	.113
Dependent variable: CPI for food away from home Independent variable:		
PPI for unprocessed foodstuffs and feedstuffs = 0	.518	.472
PPI for finished consumer food = 0	6.434	.011
PPI for unprocessed foodstuffs and feedstuffs/PPI for finished consumer food = 0	7.963	.019

consumed at home versus food consumed away from home.

In addition to playing their role in Granger causality tests, the two VARs estimated in this section were used to develop impulse response functions and variance decompositions. As with VAR-TOTAL in the previous section, the residuals were orthogonalized by a Cholesky decomposition with the following ordering: PPI for unprocessed foodstuffs and feedstuffs, PPI for finished consumer food, and CPI for food consumed at home (for VAR-HOME) or CPI for food consumed away from home (for VAR-AWAY). Chart 2 presents the accumulated impulse response functions developed from the coefficients of VAR-HOME, while chart 3 shows the response functions developed from the coefficients of VAR-AWAY.

In contrast to the Granger causality tests presented in table 3, the impulse response functions suggest that there are substantial differences in how price changes are transmitted from producer food to consumer food consumed at home versus consumer food consumed away from home. A comparison of the impulse response functions in charts 2 and 3 shows that unanticipated price changes in the PPI for unprocessed foodstuffs and feedstuffs significantly affect the CPI for food consumed at home but do not significantly affect the CPI for food consumed away from home. In addition, the impulse response functions indicate that unanticipated changes to the PPI for finished consumer food significantly affect both the CPI for food consumed at home and the CPI for food consumed away from home but that the effect is much

Chart 2. Accumulated impulse response functions from VAR-HOME

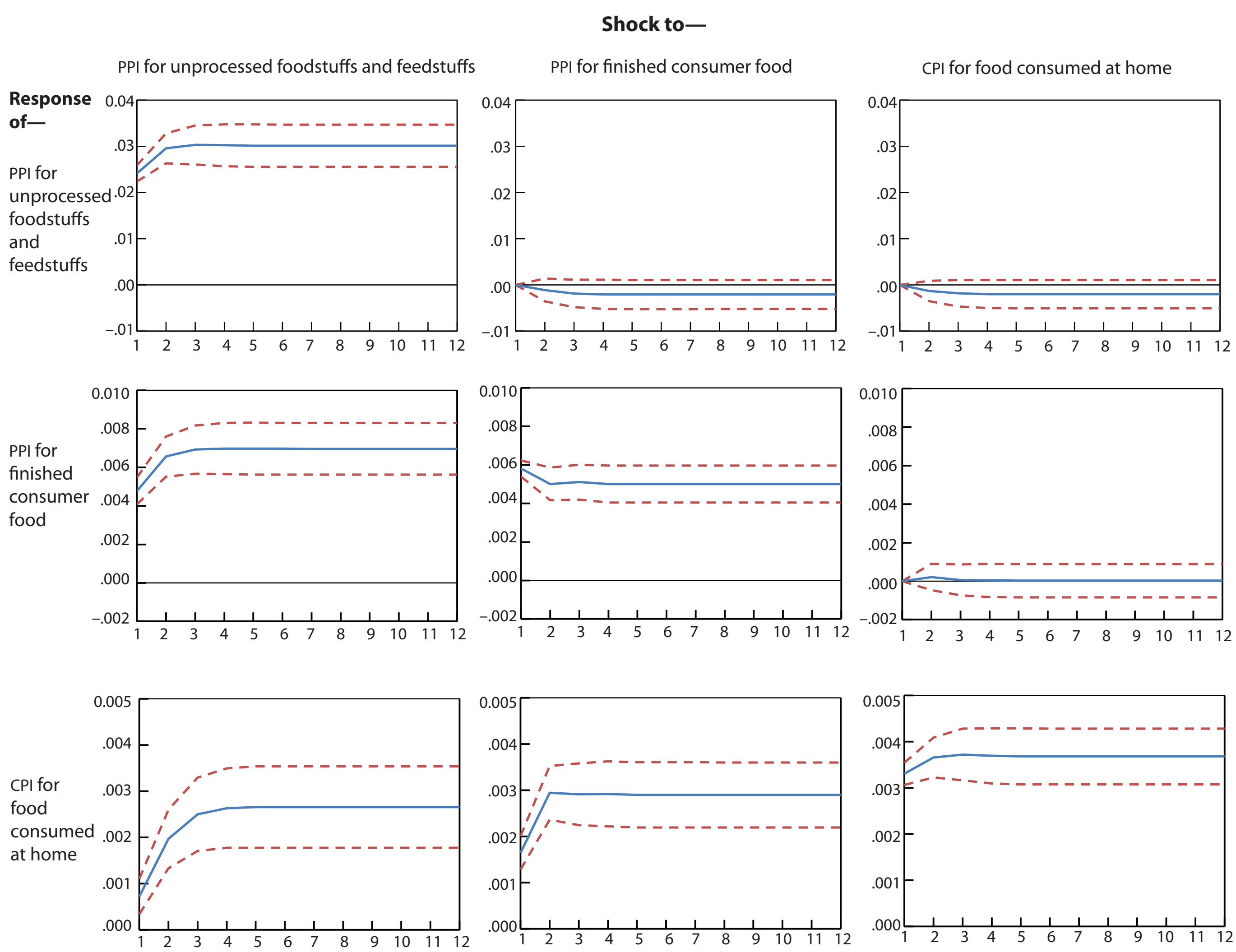
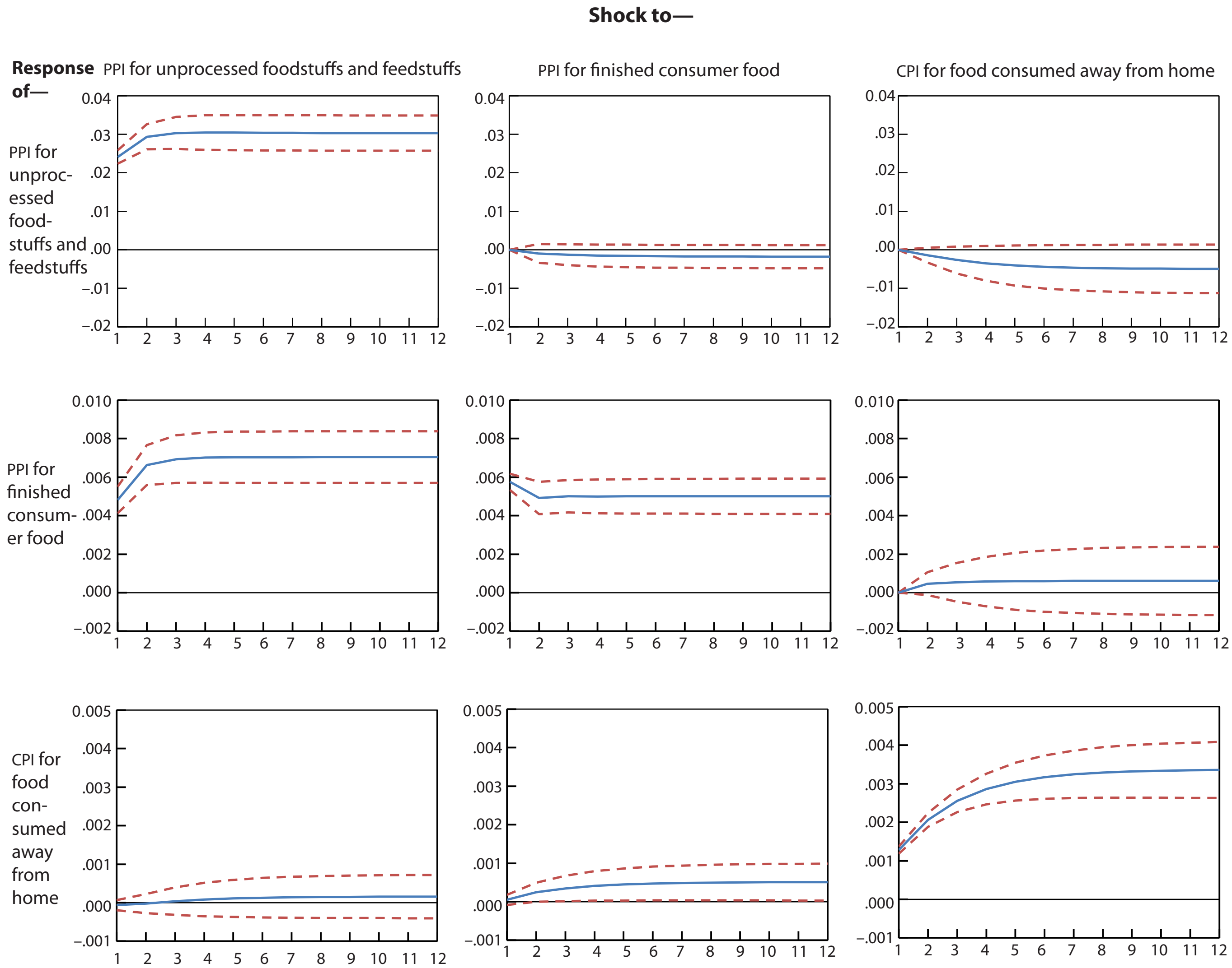


Chart 3. Accumulated impulse response functions from VAR-AWAY



stronger for food consumed at home. A one-standard-deviation (0.58-percent) shock to the PPI for finished consumer food leads to a 0.29-percent increase in the CPI for food consumed at home, but to only a 0.05-percent increase in the CPI for food consumed away from home. Furthermore, the shock to finished consumer food has an immediate effect on the CPI for food consumed at home, and the full impact of the shock occurs after 4 months. The shock to finished consumer food, by contrast, does not initially affect the CPI for food consumed away from home, and the full effects of the shock are not realized for 8 months. The impulse response function analysis, therefore, supports the hypothesis that changes to producer food prices are transmitted more strongly to consumer prices for food consumed at home than to consumer prices for food consumed away from home.

Table 4 presents the variance decompositions of VAR-HOME and VAR-AWAY. Like the impulse response functions, the variance decompositions suggest that the price transmission effects from producer food to consumer food are much stronger for food consumed at home than for food consumed away from home.

The variance decompositions in table 4 show that 13.33 percent of the forecast error variance in the CPI for food consumed at home can be attributed to unanticipated changes to the PPI for unprocessed foodstuffs and feedstuffs while 24.65 percent is attributable to the PPI for finished consumer food. Alternatively, the variance decompositions indicate that only 0.46 percent of the forecast error variance in the CPI for food consumed away from home

Table 4. Variance decompositions

Decomposition variable	Percentage of forecast error due to—		
	PPI for unprocessed foodstuffs and feedstuffs	PPI for finished consumer food	CPI for food at home
VAR-HOME			
PPI for unprocessed foodstuffs and feedstuffs	99.36	0.30	0.34
PPI for finished consumer food	43.02	56.86	.11
CPI for food at home	13.33	24.65	62.02
VAR-AWAY			
PPI for unprocessed foodstuffs and feedstuffs	99.05	.17	.77
PPI for finished consumer food	43.73	55.90	.38
CPI for food away from home	.46	2.11	97.43

can be explained by unexpected changes to the PPI for unprocessed foodstuffs and feedstuffs while 2.11 percent is explainable by the PPI for finished consumer food. The vast majority (97.43 percent) of the forecast error variance in the CPI for food consumed away from home is due to unanticipated changes in that variable itself.

THIS ARTICLE HAS PRESENTED estimated VAR models for studying price transmission through three stages of food production, the final stage of which is consumer food. The issue examined by the article was whether price transmission from producer food to consumer food differed for consumer food purchased for home consumption versus food consumed away from home.

The analysis began by estimating a VAR with three variables: the PPI for unprocessed foodstuffs and feedstuffs, the PPI for finished consumer food, and the CPI for total food. The VAR was used to test for Granger causality and to construct impulse response functions and variance decompositions. The Granger causality tests, impulse response functions, and variance decompositions all indicated that price changes are transmitted forward through the stages of food production, but not backward. For example, the impulse response functions suggested that a one-standard-deviation (2.4-percent) unanticipated increase in the PPI for unprocessed foodstuffs and feedstuffs leads to a statistically significant 0.7-percent increase in the PPI for finished consumer food and a statistically significant 0.17-percent increase in the CPI for total food and that a one-standard-deviation (0.58-percent) increase in the PPI for finished consumer food results in a statistically significant 0.21-percent rise in the CPI for total food. In no instances did an unanticipated change in a stage-of-processing food index lead to a statistically significant change in an index at an earlier stage of food production.

The analysis then estimated two separate VARs: one that included the CPI for food consumed at home as the final stage and the other that instead included the CPI for food consumed away from home as the final stage. Estimating these two VARs allowed for a separate examination of price transmission effects on food consumed at home versus food consumed away from home. The impulse response functions and variance decompositions constructed from the VARs suggest that there are substantial differences in price transmission from producer food to consumer food consumed at home versus that consumed away from home. Specifically, the impulse response functions indicate that an unanticipated change to the PPI for unprocessed foodstuffs and feedstuffs leads to a statistically significant increase in the CPI for food consumed at home but does not significantly affect the CPI for food consumed away from home. In addition, a shock to the PPI for finished consumer food significantly affects both the CPI for food consumed at home and the CPI for food consumed away from home, but the effect is much lower on the latter. A one-standard-deviation (0.58-percent) shock to the PPI for finished consumer food causes a 0.29-percent increase in the CPI for food consumed at home but just a 0.05-percent increase in the CPI for food consumed away from home. The variance decompositions tell a similar story: on the one hand, 13.33 percent of the forecast error variance in the CPI for food consumed at home can be attributed to unanticipated changes to the PPI for unprocessed foodstuffs and feedstuffs while 24.65 percent is attributable to the PPI for finished consumer food; on the other hand, only 0.46 percent of the forecast error variance in the CPI for food consumed away from home can be explained by unexpected changes to the PPI for unprocessed foodstuffs and feedstuffs while 2.11 percent is explainable by the PPI for finished consumer food. □

Notes

[1] William H. Greene, *Econometric Analysis* (Upper Saddle River, NJ, Prentice Hall, 1997); see especially pp. 815–816.

[2] David A. Dickey and Wayne A. Fuller, "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, vol. 74, 1979, pp. 427–431. Also in John Dinardo and Jack Johnston, *Econometric Methods* (New York, McGraw Hill, 1996); see especially pp. 224–225.

[3] Philip Hans Franses, *Time Series Models for Business and Economic Forecasting* (Cambridge, U.K., Cambridge University Press, 1998).

[4] Greene, *Econometric Analysis*, p. 161.

[5] Dinardo and Johnston, *Econometric Methods*, pp. 289–301.

[6] Ibid.

[7] The CPI program prices food away from home bimonthly in most CPI geographical areas. Therefore, the effects of a shock to a PPI foods index on the foods-away-from-home index may have a 1-month lag compared with the effects on the food-at-home index, which the CPI program prices monthly everywhere.