Price transmission within the PPI for intermediate goods

A more detailed stage-of-processing classification model and empirical analysis are used to examine causal price relationships; results indicate that changes in component prices produce significant movements in the PPI for finished goods

Jonathan Weinhagen

In 1978, the Bureau of Labor Statistics began emphasizing the Producer Price Index (PPI) commodity based stage-of-processing system as its main analytical structure for tracking changes in wholesale prices. This system organizes manufacturers' selling prices according to the level of processing the commodity has undergone. The three main stage-of-processing categories are crude goods, intermediate goods, and finished goods.[1] For purposes of analysis, the Consumer Price Index (CPI) could be added to the structure as a fourth "stage of processing."

The Bureau's main aggregate PPI prior to 1978, the PPI for All Commodities, includes price changes from all stages of wholesale processing. However, the all commodities index is criticized as a measure of aggregate inflation because multiple counting of prices for transactions at various stages of processing within the index may result in a magnified and distorted measurement of wholesale inflation. Multiple counting problems arise when price changes for basic commodities are passed forward through the stages-of-processing. For example, a price change in wheat that is passed forward to prices for flour and bread would be overemphasized in an aggregate index that includes price changes for all three commodities. The stage-of-processing system was developed, in part, to improve multiple counting issues within the PPI. Additionally, the stage-of-processing system allows for analysis of price transmission among the stages.

Several authors have examined the causal relationships between prices within the stage-of-processing system. S. Brock Blomberg and Ethan Harris investigated the connection between the core CPI index, on the one hand, and the Commodity Research Bureau spot index, the Journal of Commerce index, the PPI for crude goods, the National Association of Purchasing Managers Price Index, and the Federal Reserve of Philadelphia's prices paid index, on the other hand.[2] Fred Furlong and Robert Ingenito analyzed causality between CPI inflation and the Commodity Research Bureau's indexes for all commodities and raw materials.[3] Todd Clark studied the relationships between PPI stage-of-processing indexes and the CPI by building forecast models of the CPI using a vector autoregression approach.[4] Tae-Hwy Lee and Stuart Scott used vector error correction models to examine price transmission within the stage-of-processing system.[5] Jonathan Weinhagen studied the connection between the PPIs for crude goods, intermediate goods, and finished goods and the CPI by constructing impulse response functions and variance decompositions from vector autoregression models.[6] In general, previous studies found statistically significant causal relationships from prices for less processed

Jonathan Weinhagen is an economist in the Office of Prices and Living Conditions. The opinions expressed in this article are those of the author's and do not necessarily reflect those of the Bureau of Labor Statistics.

goods to prices for more complete goods. However, Blomberg and Harris; Furlong and Ingenito; Clark; and Weinhagen discovered that the relationships deteriorated in the late 1980s.[7]

This article contributes to the literature on price transmission by providing a more detailed stage-of-processing classification structure than previous analyses and empirically examining the causal price relationships within this structure. Additional detail is added to the current stage-of-processing structure by subdividing the intermediate goods index into two separate stages—one that includes prices for relatively less processed intermediate goods and one that is comprised of relatively more processed intermediate goods prices. A significant finding of this study is that the expanded stage-of-processing classification structure yields clear forward flowing causal pricing relationships during the 1990s.

This article examines the composition of the intermediate goods PPI to identify if it is feasible to subdivide the index into multiple stages of processing. It then separates the intermediate goods index into two stages of processing and uses econometric techniques to study the causal relationships between price changes at these stages. Next, it develops an economywide empirical model of price transmission within the stage-of-processing system that incorporates prices from two intermediate stages of processing. The final section concludes the discussion.

Intermediate goods

The first step of this analysis is to examine the composition of the PPI for intermediate goods in detail to determine if it is feasible to subdivide the index into multiple intermediate stages by separating out prices for relatively less and more processed commodities.

Composition. The PPI for intermediate goods comprises prices for fully or partially processed commodities that will be used as inputs to produce other goods. Specifically, the index includes prices for five types of commodities: materials, components, supplies, processed fuels and lubricants, and containers. Materials are partially processed commodities that will be further processed into other commodities. Examples of materials include plastic resins, steel wire, and treated wood. Components consist of complete commodities purchased by businesses for assembly with other commodities as inputs to production. Tires, capacitors, and metal doors are examples of components. Supplies are defined as fully processed commodities purchased by firms to be consumed during the production process, but not as part of the product being manufactured. Examples of supplies include pens, business forms, and small cutting tools.

Table 1. Relative importance values of the intermediate goods index, December 2001

Index	Relative importance
Intermediate materials, supplies, and components	100.0
Materials and components for manufacturing	47.0
Materials for food manufacturing	2.9
Materials for nondurable manufacturing	14.1
Materials for durable manufacturing	9.2
Components for manufacturing	20.9
Materials and components for construction	13.1
Processed fuels and lubricants	15.1
Manufacturing industries	6.1
Nonmanufacturing industries	9.0
Containers	3.4
Supplies	21.4
Manufacturing industries	4.7
Nonmanufacturing industries	16.7
Feeds	1.1
Other supplies	15.6

Processed fuels and lubricants are energy based commodities used by firms during production; for example, gasoline, commercial natural gas, and jet fuels. Containers are commodities such as boxes, barrels, and steel cans, which firms use during production. Table 1 presents the relative importance values of the subcategories within the intermediate goods index.

Feasibility. The subcategories of the PPI for intermediate goods include prices for commodities that have undergone differing levels of processing and are potentially inputs to each other, leading to the possibility of price-pass-through within the aggregate index. The most probable source of price transmission within the intermediate goods PPI is from materials prices to components prices. Materials are relatively less processed than components and are often used as inputs to the production of components, suggesting that price changes in materials may pass forward to prices for components. In addition to price-pass-through from intermediate materials to components, price movements in all other categories within the intermediate goods index could potentially pass through to other categories within the intermediate goods index to which they are inputs.

Empirical investigation

The next step in this analysis is to conduct an empirical examination of internal flow within the PPI for intermediate goods by analyzing the causal price relationships between the subcategories of the index using a vector autoregression model.

Vector autoregressions model the variables of a system of equations as a linear function of the past values of all variables in the system.[8]

This empirical examination focuses on estimation of a vector autoregression model using separate time series data for prices for intermediate materials and intermediate components, because materials are relatively less processed than components and are often used as inputs to their production. The time frame, 1990 to 2002, was chosen for estimation of the vector autoregression model because studies by Blomberg and Harris, Clark, Furlong and Ingenito, and Weinhagen found a significant change in the price transmission relationships within the PPI and CPI in the mid- to late 1980s.[9]

The current PPI structure includes materials indexes for nondurable manufacturing, durable manufacturing, and food manufacturing; however, an aggregate materials index is not available. Accordingly, an aggregate index comprised of the PPIs for materials for durable and nondurable manufacturing was constructed using current BLS index methodology.[10] The PPI for food manufacturing was excluded from the aggregation because commodities included in this index are less likely to be used as inputs to components. The weights used in the construction of the index are from the Census of Manufacturing and were adjusted in each period by the movements of the indexes. The constructed materials index and the PPI for components were both seasonally adjusted and converted to annualized percentage growth form. Dickey-Fuller tests were conducted to determine if the indexes expressed in annualized percentage growth form are stationary.[11] 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 vector autoregression invalidates conventional significance tests of models' coefficients and can treat insignificant correlations between variables as significant, even if both variables follow mostly independent trends. The Dickey-Fuller tests included trend and intercept terms and sufficient lags to ensure white-noise residuals. The tests indicate that both time series are stationary.

To determine the appropriate lag length of the vector autoregression, the Schwarz criterion was implemented.[12] The criterion suggests that a first-order vector autoregression model is optimal. Accordingly, a vector autoregression with one lag of the monthly seasonally adjusted price indexes for intermediate materials and intermediate components was estimated using data from 1990 to 2002.

The unrestricted vector autoregression model was used to conduct bidirectional Granger causality tests. A variable is said to Granger cause a second variable when adding past values of the variable to an autoregressive model of a second variable improves the predictability of the second variable. Wald statistics were used to test the null hypothesis of 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.[13] A small *p* (probability) value of the Wald statistic rejects the null hypothesis of 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 .01 indicates rejection of the null hypothesis at the 99-percent confidence level, whereas a *p* value of .05 or less indicates rejection of the null hypothesis at the 95-percent confidence level. Values of *p* that are greater than .05 suggest acceptance of the null hypothesis of no Granger causality. The following tabulation presents the results of the Granger causality tests.

Null hypothesis:	*P value*
PPI for materials does not Granger cause PPI for components	0.027
PPI for components does not Granger cause PPI for materials	.241

The Wald statistics indicate that, at the 95-percent confidence level, changes in materials prices Granger cause component prices, but changes in component prices do not Granger cause materials prices. The presence of Granger causality between prices for materials and components suggests that internal price flow and multiple counting may be present in the index for intermediate goods.

Vector autoregression coefficients are difficult to interpret due to the multivariate nature of the models. Accordingly, impulse response functions and variance decompositions were developed to assist in interpretation of vector autoregressions. Impulse response functions measure the effect of a one-standard-deviation innovation 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 vector autoregression explained by innovations to all variables within the vector autoregression.[14]

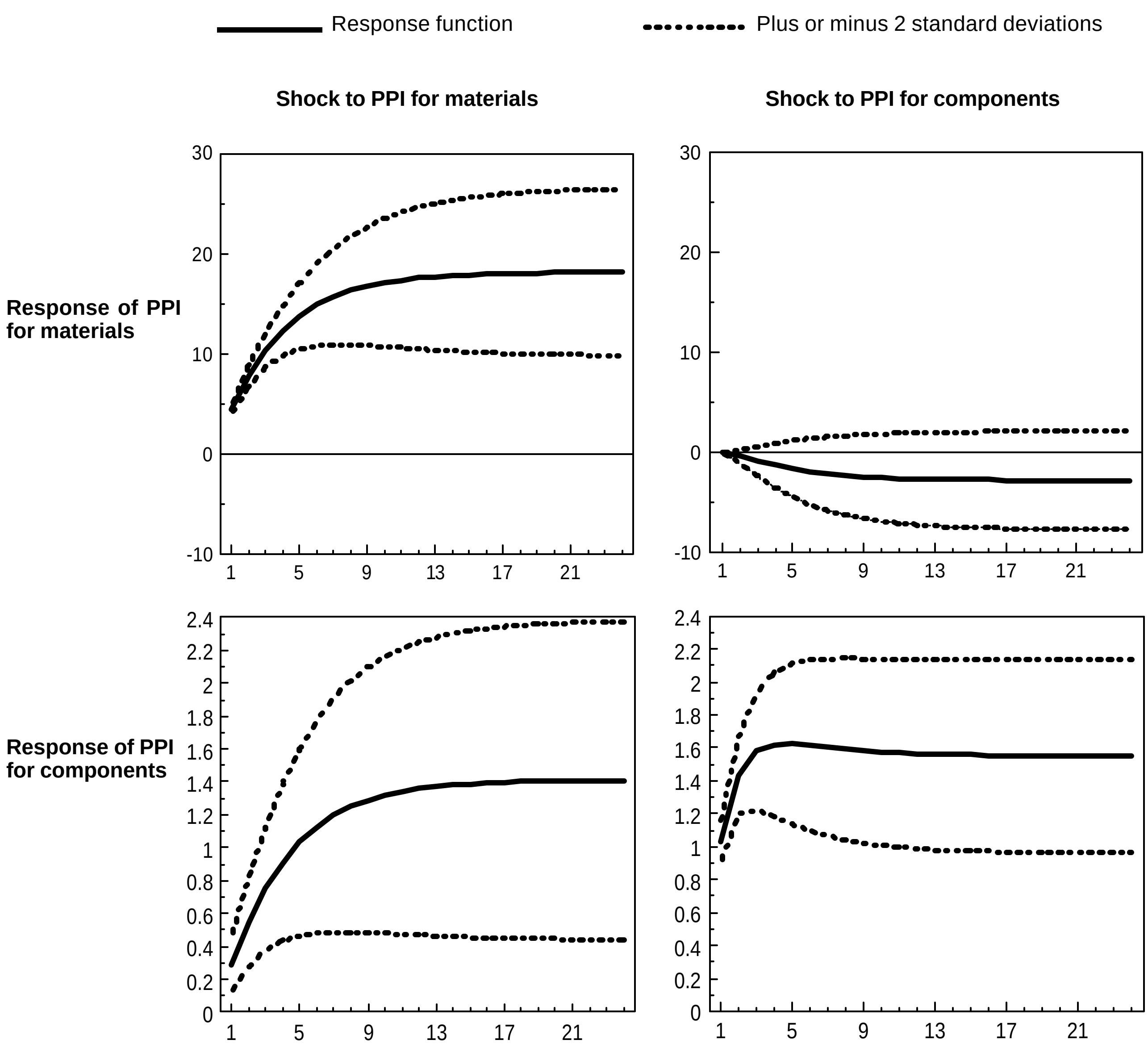
Because innovations within a vector autoregression are generally not contemporaneously independent of each other, a random innovation to one variable often occurs simultaneously with innovations to other variables. To overcome this problem, the residuals may be orthogonalized by a Cholesky decomposition in which the covariance matrix of the residuals is lower triangular. Therefore, an innovation to one variable in the system contemporaneously affects only variables ordered after that variable in the vector autoregression.[15]

The residuals of the vector autoregression were orthogonalized by a Cholesky decomposition in which materials prices were ordered prior to components prices. This ordering was chosen because materials are often used as inputs to the production of components. In addition, the Wald tests indicate that materials prices Granger cause components prices. Subsequent to orthogonalization of the residuals, impulse response functions and variance decompositions were constructed from the vector auto-regression coefficients.

Chart 1 presents the accumulated impulse response functions of one-standard-deviation shocks to materials and components prices. Using EVIEWS4.0, standard error bands were constructed to represent the statistical significance of the impulse response functions.[16] The impulse responses are significant at the 95-percent confidence level when both standard error bands are simultaneously above or below zero on the y-axis.

The accumulated impulse response functions in chart 1 show that price changes for materials transmit forward to components prices. Specifically, a 4.5-percent (one-standard-deviation) unanticipated increase in materials prices results in a 1.4-percent increase in prices for components. By contrast, changes in prices for components do not result in significant movements in materials prices. The impulse

Chart 1. Accumulated impulse response functions



response functions imply a significant causal relationship from materials prices to components prices, suggesting multiple counting in the intermediate goods prices index.

The variance decompositions presented in the following tabulation also indicate a causal relationship from materials prices to components prices. After 24 months, innovations to the PPI for materials account for nearly 17 percent of the component price index's forecast error variance, whereas innovations to components prices explain less than 2 percent of the forecast error variance of the PPI for materials.

Variance decompositions after 24 months

Decomposition variable	*Percent of forecast errors due to:*	
	PPI for materials	*PPI for components*
PPI for materials	98.17	1.83
PPI for components ...	16.91	83.09

As discussed earlier, in principle there is a circular input-output relationship between prices for materials and components, as well as other pair-wise stage-of-processing prices; however, in practice this relationship is overwhelmingly forward flowing. The results from the impulse response functions and variance decompositions support this conclusion, as both tests indicate only forward price transmission from materials to components.

An economywide model

Previous empirical analyses by Lee and Scott and Weinhagen of the causal price relationships within the stage-of-processing system utilizing PPI data have included price indexes for crude goods, intermediate goods, finished goods, and the CPI.[17] This section develops a vector autoregression model of price transmission within a stage-of-processing framework in which prices for intermediate materials and intermediate components are included in the regression equations, as opposed to the aggregate intermediate goods index.

Table 2. ***P* values of Granger causality tests**

Test	*P* value
Dependent variable: PPI for crude	
Null hypothesis	
PPI for materials does not Granger cause PPI for crude	0.180
PPI for components does not Granger cause PPI for crude	.415
PPI for finished does not Granger cause PPI for crude	.050
CPI does not Granger cause PPI for crude	.088
PPI for materials/PPI for components/PPI for finished/CPI do not Granger cause PPI for crude	.100
Dependent variable: PPI for materials	
Null hypothesis	
PPI for crude does not Granger cause PPI for materials	.005
PPI for components does not Granger cause PPI for materials	.363
PPI for finished does not Granger cause PPI for materials	.774
CPI does not Granger cause PPI for materials	.378
PPI for components/PPI for finished/CPI do not Granger cause PPI for materials	.490
Dependent variable: PPI for components	
Null hypothesis	
PPI for crude does not Granger cause PPI for components	.458
PPI for materials does not Granger cause PPI for components	.015
PPI for crude/PPI for materials do not Granger cause PPI for components	.042
PPI for finished does not Granger cause PPI for components	.342
CPI does not Granger cause PPI for components	.261
PPI for finished/CPI do not Granger cause PPI for components	.240
Dependent variable: PPI for finished	
Null hypothesis	
PPI for crude does not Granger cause PPI for finished	.589
PPI for materials does not Granger cause PPI for finished	.669
PPI for components does not Granger cause PPI for finished	.036
PPI for crude/PPI for materials/PPI for components do not Granger cause PPI for finished	.203
CPI does not Granger cause PPI for finished	.634
Dependent variable: CPI	
Null hypothesis	
PPI for crude does not Granger cause CPI	.073
PPI for materials does not Granger cause CPI	.827
PPI for components does not Granger cause CPI	.086
PPI for finished does not Granger cause CPI	.005
PPI for crude/PPI for materials/PPI for components/PPI for finished do not Granger cause CPI	.004

Chart 2. **Accumulated impulse response functions**

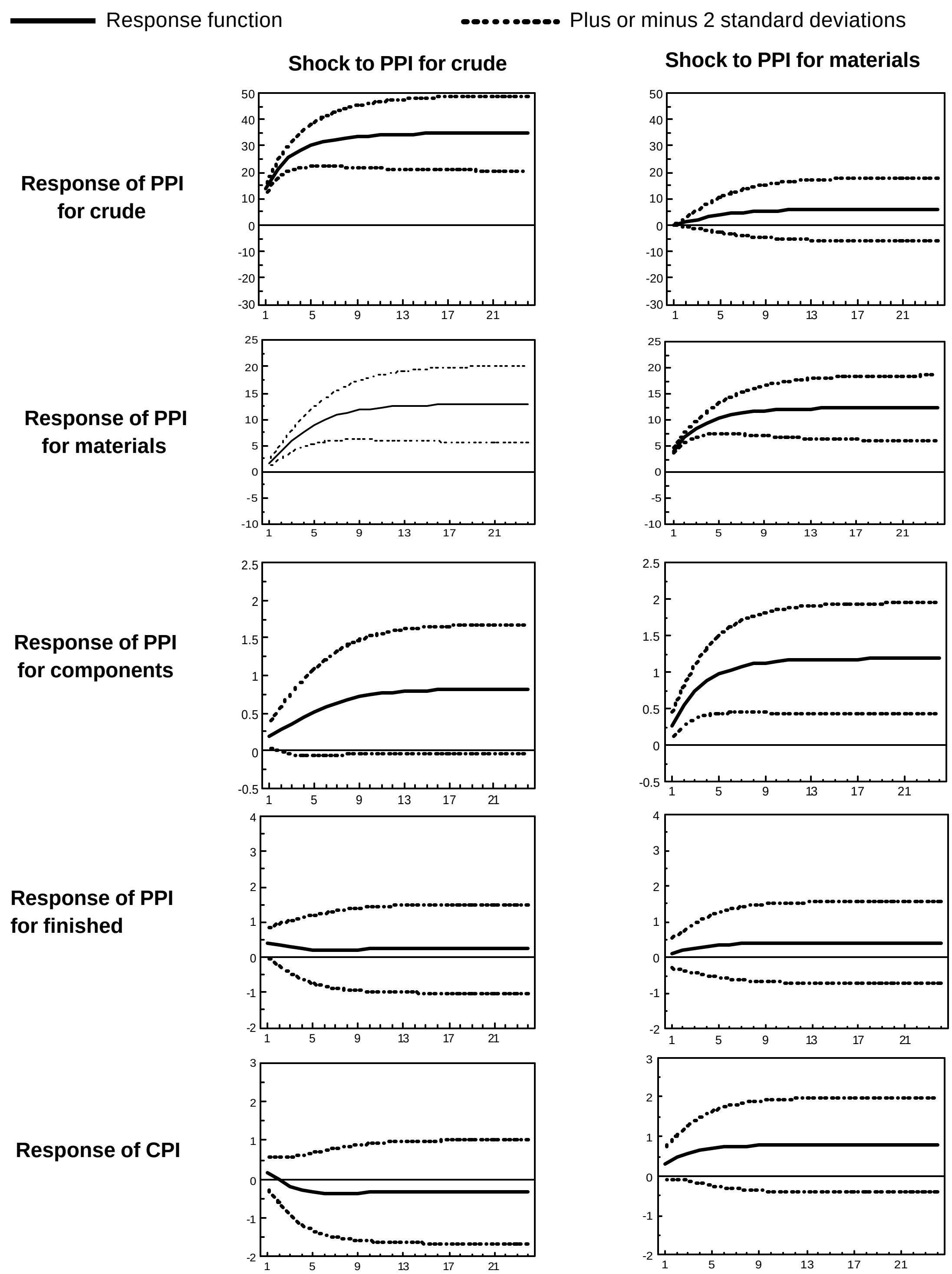
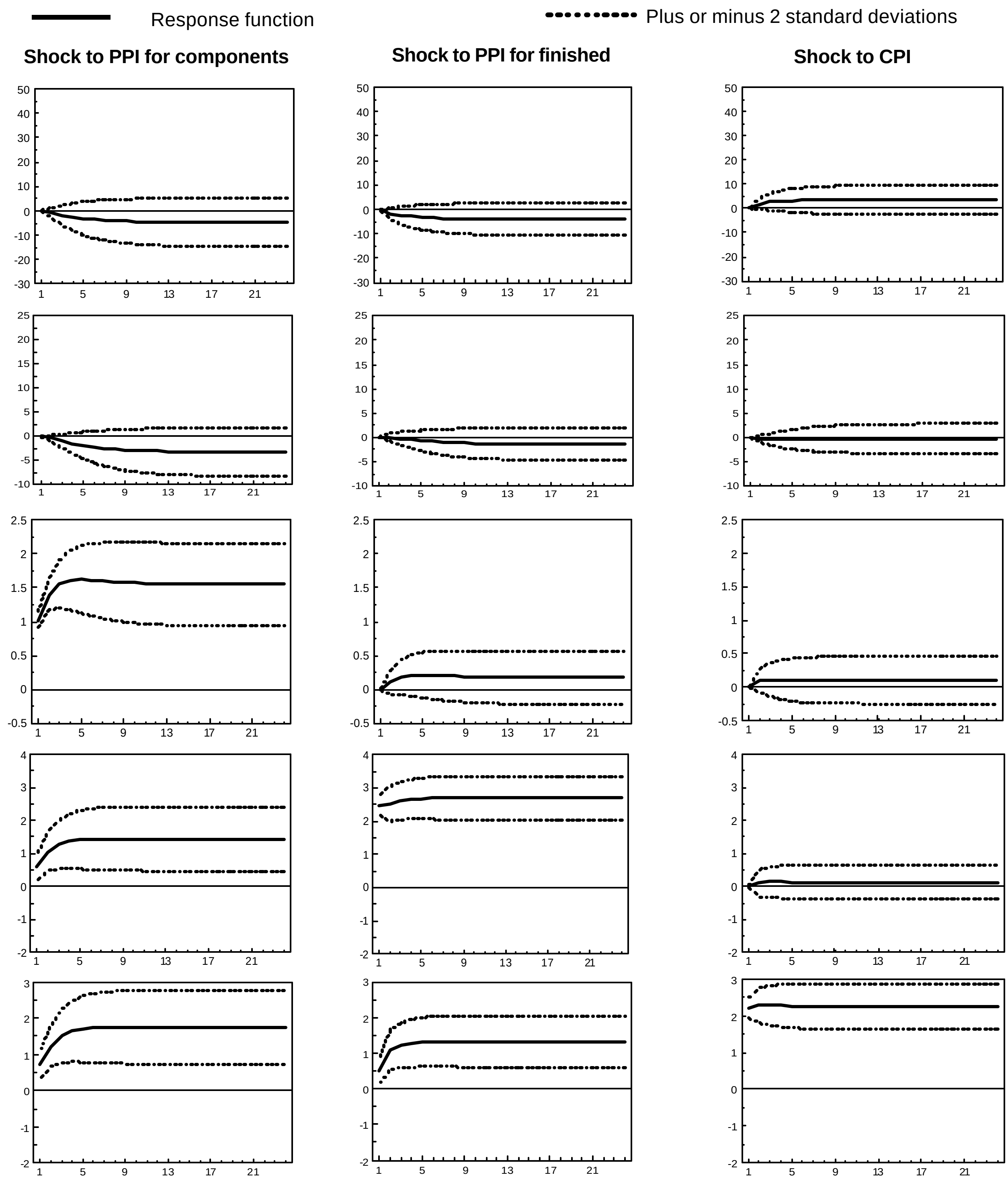


Chart 2. **Continued —Accumulated impulse response functions**



The vector autoregression model was constructed using monthly PPI data for crude goods, intermediate materials, intermediate components, and finished goods, and the CPI for commodities from 1990 to 2002 as published by BLS. The indexes excluded food and energy prices, and were seasonally adjusted and converted to annualized percentage growth form. Dickey-Fuller tests indicate that the indexes in annualized percentage growth form are all stationary. To determine the correct lag structure of the vector autoregression model, the Schwarz information criterion was implemented. The criterion suggests that a vector autoregression whose equations have one lag is optimal; therefore, the vector autoregression was estimated using one lag of all variables.

Wald tests were performed to examine Granger causality among the indexes. Table 2 (page 45) presents the results of the Granger causality tests. In addition to testing for Granger causality from individual indexes to the dependent variable, this analysis tested the joint lagged values of all variables at stages of processing prior and subsequent to the dependent variable for Granger causality. For example, the null hypothesis that prices for crude goods and intermediate materials do not jointly Granger cause intermediate components prices is indicated in table 2 as PPI for crude/PPI for materials do not Granger cause PPI for components.

The Granger causality tests in all of the equations suggest significant correlation at the 95-percent confidence level between commodity prices at stages of processing *prior* to the dependent variable. The Wald statistics show that in the equations for materials prices, components prices, and the CPI for commodities, the combined lagged values of prices at stages of processing *prior* to the dependent variable are jointly significant. In the finished goods prices equation, although the combined lagged values of prices for crude goods, materials, and components are not jointly significant, the lagged values of components prices are statistically significant. Alternatively, with the exception of lagged values of finished goods prices in the crude goods equation, the Wald statistics indicate that lagged values of prices at stages of processing *subsequent* to the dependent variable are not significantly correlated with the dependent variable at the 95-percent confidence level.

Impulse response functions and variance decompositions were constructed from the orthogonalized set of residuals. The residuals were orthogonalized using a Cholesky decomposition with the following ordering: PPI crude, PPI materials, PPI components, PPI finished goods, CPI commodities. This ordering was chosen because economic theory predicts prices to transmit forward through the stages of processing as input price changes are passed on to higher level producers. In addition, the Granger causality tests suggest that this ordering is correct. The accumulated impulse response functions are presented in chart 2. (See pages 46 and 47.)

The accumulated impulse response functions indicate that price changes within the stage-of-processing system are passed forward through the stages. This result is most clearly illustrated by examining the stage-ahead responses of price shocks throughout the stage-of-processing system. In every instance, an unanticipated price shock results in a statistically significant change in prices one-stage-ahead of where the shock occurred. For example, a shock to materials prices results in a significant movement in the components PPI, a components price shock causes the index for finished goods prices to change, and a random innovation in the finished goods PPI causes a change in the commodities CPI. In addition, the analysis indicates that a shock to the components PPI also significantly affects the CPI for commodities. The response of the commodities CPI to components prices is of particular interest because a previous study, using data from 1990 to 2001, found that price changes of intermediate goods do not cause price changes in the CPI for commodities.[18] By contrast, the impulse response functions imply that price movements are not passed backwards through the stages of processing. In no instances do prices shocks within the stage-of-processing system produce statistically significant price movements of indexes at stages of processing prior to the stage at which the shock originated.

The variance decompositions also indicate that price changes are transmitted forward through the stages of processing. Table 3 shows that the percentage of forecast error variance due to price innovations occurring one-stage-prior to the decomposition variable is substantial in every case. Innovations to crude goods prices account for approximately 38 percent of the forecast error variance in materials prices; shocks to the materials PPI explain around 14 percent of the forecast error variance in components prices, innovations to components prices account for close to 9 percent of the forecast error variance in the finished goods PPI, and unanticipated changes in finished goods prices explain approximately 9 percent of the forecast error variance in the CPI for commodities. In addition, whereas one study showed that only a small portion of the forecast error

Table 3. Variance decompositions after 24 months

Decomposition variable	Percentage of forecast errors due to: PPI for crude	PPI for materials	PPI for components	PPI for finished	CPI
PPI for crude	94.55	1.51	0.97	1.47	1.50
PPI for materials	38.32	58.63	2.35	.47	.23
PPI for components	5.00	14.52	78.66	1.19	.63
PPI for finished	2.55	.44	8.88	87.97	.16
CPI	1.43	2.16	13.37	9.52	73.53

variance in the CPI for commodities can be accounted for by intermediate goods price shocks, by subdividing the overall intermediate goods index into two separate stages, intermediate prices at the component level explain more than 13 percent of the forecast error variance in the commodities CPI.[19]

Alternatively, the variance decompositions do not indicate that price changes are passed backward through the stages of processing.

Conclusion

The PPI for intermediate goods comprises prices for commodities that have undergone varying degrees of processing. This article used a vector autoregression methodology to examine the causal relationships between prices for relatively less processed goods and relatively more complete commodities within the PPI for intermediate goods. The analysis began by constructing a bivariate vector autoregression model using data from 1990 to 2002 of the PPIs for intermediate materials and components. Impulse response functions and variance decompositions implied that a price shock to materials caused a significant positive change in the PPI for components, but that an innovation to components prices did not result in a change in the materials PPI. These results indicate forward price flow within the PPI for intermediate goods and suggest that multiple counting may occur within the aggregate index.

Utilizing the fact that the aggregate intermediate goods index can be divided into multiple stages, an economywide vector autoregression model, which included the PPIs for crude goods, intermediate materials, intermediate components, finished goods, and the CPI for commodities was developed to study the causal price relationships between various stages of processing. Impulse response functions and variance decompositions constructed from the vector autoregression's coefficients implied that price changes pass forward through the stage-of-processing system. In all instances, the impulse response functions showed that price shocks within the system caused statistically significant changes in prices at the stage one-step-ahead of where the shock occurred. The findings that changes in component prices result in significant movements in both the PPI for finished goods and the CPI for commodities are of particular interest because previous analysis suggested that the causal relationships from the PPI for intermediate goods to the PPI for finished goods and the CPI deteriorated during the 1990s.[20] □

Notes

[1] For more information, see *Bureau of Labor Statistics Handbook of Methods*, ch. 14, "Producer Price Indexes," on the Internet at **www.bls.gov/opub/hom/pdf/homch14.pdf**.

[2] S. Brock Blomberg and Ethan Harris, "The Commodity-Consumer Price Connection: Fact or Fable?" *Federal Reserve Bank of New York Economic Policy Review*, October 1995, pp. 21–38.

[3] Fred Furlong and Robert Ingenito, "Commodity Prices and Inflation," *Federal Reserve Bank of San Francisco Economic Review*, 1996, no. 2, pp. 27–47.

[4] Todd Clark, "Do Producer Prices Lead Consumer Prices?" *Federal Reserve Bank of Kansas Economic Review*, third quarter, 1995, pp. 26–39.

[5] Tae-Hwy Lee and Stuart Scott, "Investigating Inflation Transmission by Stages of Processing," in Robert Engle and Halbert White, eds., *Cointegration, Causality, and Forecasting: A Festschrift in Honor of Clive W.J. Granger*, ch. 12 (England, Oxford University Press, August 1999), pp. 283–300.

[6] Jonathan Weinhagen, "An Empirical Analysis of Price Transmission by Stage of Processing," *Monthly Labor Review*, November 2002, pp 3–11.

[7] Harris and Blomberg, "The Commodity-Consumer Price Connection: Fact or Fable?" 1995, Furlong and Ingenito, "Commodity Prices and Inflation," 1996; Clark, "Do Producer Prices Lead Consumer Prices?" 1995; and Weinhagen, "An Empirical Analysis of Price Transmission," 2002.

[8] William Greene, *Econometric Analysis* (Upper Saddle River, New Jersey, Prentice-Hall Inc., 1997), pp. 815–16.

[9] Blomberg and Harris, "The Commodity-Consumer Price Connection: Fact or Fable?" 1995; Clark, "Do Producer Prices Lead Consumer Prices?" 1995; Furlong and Ingenito, "Commodity Prices and Inflation," 1996; and Weinhagen, "An Empirical Analysis of Price Transmission," 2002.

[10] See *Handbook of Methods*, on the Internet at **www.bls.gov/opub/hom/pdf/homch14.pdf**.

[11] David Dickey and Wayne Fuller, "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, vol. 74, 1979, pp. 427–31.

[12] Philip Hans Franses, *Time Series Models for Business and Economic Forecasting* (Cambridge, United Kingdom, Cambridge University Press, 1998).

[13] Greene, *Econometric Analysis*, 1997, p. 161.

[14] John Dinardo and Jack Johnston, *Econometric Methods* (New York, McGraw Hill, College Division, 1996), pp. 289–301.

[15] Dinardo and Johnston, *Econometric Methods,* 1996.

[16] EVIEWS 4.0 is a software program.

[17] Lee and Scott, "Investigating Inflation Transmission by Stages of Processing," 1999 and Weinhagen, "An Empirical Analysis of Price Transmission," 2002.

[18] Weinhagen, "An Empirical Analysis of Price Transmission," 2002.

[19] *Ibid*.

[20] *Ibid*. Weinhagen showed these causal relationships.