TRANSMISSION OF PRODUCER PRICES THROUGH STAGES OF PROCESSING

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1. Introduction

At the time of the 1973-74 oil price shock, the featured index for the U.S. Bureau of Labor Statistics (BLS) Producer Price Index (PPI) program was "All Commodities". For some time, this index was dominated by oil prices as their effects spread to refined petroleum producers and other producers experiencing higher energy prices. Critics complained that the single summary index gave a very limited picture of what was happening in prices. In 1978, BLS shifted its publication emphasis to a stage of processing (SOP) system. As explained by Gaddie and Zoller (1988),

> The basic idea of a stage of process system is that the economy can be subdivided into distinct economic segments which can be arranged sequentially so that the outputs of earlier segments become inputs to subsequent ones, up through final demand.... To the extent that such a sequential system of processing stages can be defined, it is possible to trace the transmission of price change through the economy and to develop information on both the timing and magnitude of price pass-throughs to final demand.

Blanchard (1987), Clark (1995), Baillie (1989), Boughton & Branson (1991), and many others have looked for evidence of price transmission among stages or for evidence that producer price increases presage consumer price increases. Both Blanchard and Clark find some explanatory power from the stages, but Clark and others find the relationships to be weak, especially in the sense of foretelling consumer price changes. Baillie and Boughton & Branson find that there is no discernible long-run relationship between commodity or producer prices and the CPI (the two time series are not cointegrated), yet Boughton & Branson find a weak short-run relationship in which commodity prices help predict future CPI inflation, while Baillie does not.

This study, still in progress, is part of a BLS effort to examine the usefulness of SOP's, including comparisons of alternative partitions of covered industries. The study employs multiple time series methods, and benefits from greater data availability for some of the indexes than some of the previous studies. The focus of the present paper is on price transmission among stages of producer prices and on transmission to consumer prices. Our results show that consumer prices are strongly related to Finished Goods prices, and that meaningful relationships exist between processing stages to be defined and discussed below.

2. Stages of Processing

The initial SOP system (Popkin, 1974) is based on allocating products or commodities to three stages, Crude, Intermediate, and Finished, based on their degree of fabrication and end use. These will be denoted CSOP, since they are commodity-based. The Finished Goods index, representing goods nearest final consumption, is usually emphasized in press releases. Crude and Intermediate indexes may be viewed as possible indicators of future movements in Finished Goods.

A second SOP system (Gaddie & Zoller, 1988), denoted ISOP, with data available from June 1985, dovetails with an improved, industry-based sample design, introduced gradually over the 1978-1986 period. In statistical terms, the redesign represents probability sampling of products made by individual industries under the Standard Industrial Classification (SIC) system. In conceptual terms, the ISOP's represent an interindustry flow model for the economy. Using the Bureau of Economic Analysis Input/Output (I/O) tables, transaction flows between producing and consuming industries can be estimated. Four stages, Crude, Primary, Semifinished, and Finished Goods producers, are derived as weighted averages of component SIC indexes. In addition, "input" indexes, input to one of the above stages or to Final Demand, can be estimated. These again use I/O table data and are based on the assumption that input products to consuming industries come proportionally from industries making these products.

Tables 1 and 2 show ISOP industry composition and transaction flow. Overall, the Crude stage represents about 10% of covered transactions, and the other stages roughly 30% each. The CSOP distribution for the three stages Crude, Intermediate, and Finished is roughly 10-50-40. Since these stages are formed by putting together commodities, wherever made, other statistics like those in Tables 1 and 2 are not available for the CSOP. Following many analysts, we emphasize "core" SOP's, that is, indexes which exclude Food and Energy sectors, each representing about 15% of the total (Table 1A). These components are obviously important, but their volatility may mask other relationships in the data. For core ISOP's, from Table 1B, Primary is reduced to about 20%, and the last two stages increase somewhat.

Table 1. Composition of ISOP's by Industry Sector (based on 1992 value of shipments).

A. Transactions (billions of dollars)

	Crude	Primary	Semifinished	Finished	Total
Food	39.4	134.9	200.3	198.7	573.3
Energy	138.7	389.8	0	0	528.5
Core	253.0	543.8	858.4	831.8	2487.0
Total	431.1	1068.5	1058.7	1030.5	3588.8

B. Percent Allocation among SOP's

	Crude	Primary	Semifinished	Finished	Total
All	12	29	30	29	100
Core	10	22	34	34	100

C. Industry Sector Distribution within Core SOP's

Industry Sector	Crude	Primary	Semifinished	Finished
Mining	6	1	0	0
Nondurable manufacturing	75	53	30	22
Durable manufacturing	19	46	70	78
Total	100	100	100	100

Table 2. Transaction Flows among ISOP's

A. Transaction Flows (%)

Producing Stage	Consuming Stage 1	2	3	4	Final Demand	Total
1	22	23	9	17	29	100
2	8	14	21	20	37	100
3	6	6	11	34	43	100
4	2	2	1	5	90	100

B. Flow Summary (%)

Backward	Internal	Forward (1)	Skip
6	11	53	30

Source: Soon Paik (BLS, 1996)

As a starting point for partitioning industries into stages, an I/O table, a matrix like Table 2, but with roughly 500 detailed industries, shows transaction flows between producing and consuming industries. As indicated in the SOP definition, the aim is to order these industries so that for a given row, representing a producing industry, most of the output is to subsequent industries, i.e., to industries to the right of the matrix diagonal. Companies, however, make such a variety of products, and their products are consumed by such a variety of industries, that no ordering produces a purely upper triangular matrix. Gaddie & Zoller's efforts to maximize "forward flow" and limit "internal flow" (consumption within the stage where produced) and "backflow" (consumption by previous stages) are rather successful. The flow summary of Table 2 shows that the ISOP achieves a forward flow exceeding 80%, while backflow and internal flow are 6% and 11%, respectively. A shortcoming, however, is that 30% of transactions skip one or more stages. For example, roughly 30-40% of output of each of the first three stages goes to Final Demand. Thus, for instance, output from Primary differs considerably from input to Semifinished. This has led to the construction of the input indexes. Since these indexes are indirectly constructed, using simplifying assumptions, they are not as firmly based as the output indexes. Currently, BLS is examining additional industry partitions.

Briefly describing the flows among stages in the ISOP in Table 2, output from Crude is about one-quarter each to Crude, Primary, and Final Demand, with the rest divided between Semifinished and Finished. From Primary, about 20% each are consumed by Finished, Semifinished, and the combination of Crude and Primary, with the remainder, close to 40%, to Final Demand. Nearly 80% of Semifinished goes to Finished or to Final Demand, and 90% of Finished goes to Final Demand. Caution in interpreting Table 2 numbers is advised, since it is based on I/O data for all industries, while, as seen in Table 1, the current ISOP industry coverage is quite limited. (In recent years, many indexes in the service-producing industries have been added, but they are not yet in the existing ISOP's).

Success in analyzing price transmission among stages and to consumer prices has been limited. For example, Clark (1995) compares forecast performance of the Core CPI (All Items, Less Food and Energy) and the Core Goods CPI (omitting services) in VAR models with and without the three CSOP's over the period 1977-1994. For the entire period, there are modest gains from including the PPI indexes, but for certain subperiods, forecast error is larger. Clark points out that a shortcoming of his results are the use of full SOP's for the PPI data and core indexes for the CPI, for data availability reasons.

Blanchard (1987) argues for nominal rigidity in both wages and prices. That is, nominal wages and prices respond slowly to forces acting on them, including each other. The rigidity on the prices side is perhaps less accepted by economists in general. Individual price chain equations with CSOP's show fairly rapid response of wages to price shocks and vice versa. These two results are consistent with a cumulation hypothesis that short lags in price transmission at detailed levels become relatively long lags at the aggregate level. He forms four regression equations with response variables personal consumption deflator, PPI Finished Nonfood Consumer Goods, PPI Finished Food, and PPI Intermediate Nonfood Goods. These equations include an input price index and a wage variable as explanatory variables, and both input prices and wages have significant long-run effects.

Mattey (1990), who makes an extra effort to extend the ISOP data available at the time, has the only analytic study we have seen which explicitly compares CSOP and ISOP. Starting from a Cobb-Douglas formulation, he obtains a model of output prices as a function of input prices and labor and capital costs. Pointing out large flow differences between output from one stage and input to the next stage, due to skips and leakage, in the ISOP equations he uses the ISOP input indexes for input prices, an advantage with the ISOP. Modeling diagnostics and forecast performance are similar for the two sets of equations. However, Mattey prefers the ISOP results, since the regression coefficients are more in accord with economic theory.

3. Modeling Price Transmission

In this section we describe how restricted vector autoregressions can be employed to examine the sources of inflation and its transmission (direction, speed, and magnitude). We show how the cointegration restriction can be used to identify a VAR system with common stochastic trends, subject to permanent and transitory changes in inflation rates, and how we may investigate the system's responses to the permanent shocks, i.e., to innovations to the stochastic common trends.

We begin with some assumptions. Let $X_t = (x_{1t} \cdots x_{pt})'$ be a PPI SOP system with p stages. For example, in the ISOP output index system, $p = 4$, and the elements of X_t are PPI indexes for Crude, Primary, Semifinished, and Finished processors. Let X_t be I(1) and cointegrated with cointegrating rank r (that is, there exists a $p \times r$ matrix β of rank $r\ (< p)$ such that $\beta' X_t$ is I(0)). Then the system can be generated from the common trend representation

$$X_t = X_0 + \mu t + Ah_t + \tilde{X}_t, \quad (1)$$

where X_0 is the initial value at $t = 0$, μ is $p \times 1$, A is $p \times (p-r)$, h_t is $(p-r) \times 1$ I(1) common stochastic trends, and $\tilde{X}_t$ consists of $p \times 1$ I(0) transitory components. Apart from the initial values and the deterministic trend, X_t can thus be decomposed into $X_t^P = Ah_t$ and $X_t^T = \tilde{X}_t$. The elements of X_t can be explained in terms of a smaller number $(p-r)$ of I(1) variables, h_t, which are thus called common factors.

Because an SOP system is constructed based on the principle of maximizing forward flow and minimizing backward flow, it will be assumed that the price indexes in the later stages include the permanent components of the previous stages (x_{i+1}^P contains $x_i^P, i = 1,2,\cdots,p-1$), but not vice versa. No such assumption is imposed for the transitory component X_t^T. As seen in Table 2, backflow represents only 5.8% of the total shipments in ISOP. Reflecting this, we make an assumption on the structure of the matrix A:

Assumption 1. The $p \times (p-r)$ factor loading matrix A can be written $\tilde{A}\Theta$, where Θ is a $(p-r) \times (p-r)$ lower triangular matrix.

Then the permanent component is

$$X_t^P = Ah_t = \tilde{A}\Theta h_t \equiv \tilde{A} f_t,$$

where h_t and f_t are vectors of size $(p-r)$.

Let η_{it} $(i = 1,\cdots,p-r)$ be the innovation to each stochastic trend h_{it}, i.e., $h_{it} = h_{i,t-1} + \eta_{it}$. Define $\eta_t = (\eta_t^{1\prime} \;\; \eta_t^{2\prime})'$ such that η_t^1 consists of η_{it} $(i = 1,\cdots,p-r)$ and η_t^2 is $r \times 1$. η_t^1 may be called the permanent shock because it determines X_t^P, while η_t^2 may be called the transitory shock. If it is true that supply shocks are persistent and demand shocks are transitory, if cost-push inflation may be persistent in the long run while the demand-pull inflation is only temporary, then η_t^1 can be referred to as the supply shock and η_t^2 as the demand shock.

Next, we make an assumption on the matrix $\tilde{A}$. Suppose for now that $E(\Delta X_t = 0)$, and that the $p \times r$ matrix of r cointegrating vectors is $\beta = (-\phi \;\; I_r)'$, where ϕ is the $r \times (p-r)$ submatrix of unknown parameters to be estimated and I_r is the identify matrix of dimension r. We assume there is no additional restriction on ϕ. The triangular representation for X_t is

$$\Delta X_t^1 = u_t^1, \qquad X_t^2 = \phi X_t^1 + u_t^2$$

where X_t is partitioned as $(X_t^{1\prime} \;\; X_t^{2\prime})'$, X_t^1 is $(p-r) \times 1$ and X_t^2 is $r \times 1$, and $u_t = (u_t^{1\prime} \;\; u_t^{2\prime})'$ is a stationary stochastic process with full rank spectral density matrix. This representation has been used by Phillips (1991), Campbell (1987), and Stock & Watson (1993).

Assumption 2. $f_t = X_t^{1P}$, where $X_t^P = (X_t^{1P\prime} \;\; X_t^{2P\prime})'$, the partition conformable with $X_t = (X_t^{1\prime} \;\; X_t^{2\prime})'$.

Under Assumption 2, the first $(p-r)$ rows of $\tilde{A}$ form an identity matrix. With $p = 4$ stages and $r = 1$,

$$\tilde{A} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \phi_1 & \phi_2 & \phi_3 \end{pmatrix},$$

with $\beta = (-\phi \;\; I_r)' = (-\phi_1 \;\; -\phi_2 \;\; -\phi_3 \;\; 1)'$. Also, $x_{it}^P = f_{it}$, $i = 1,2,3$, and $x_{4t}^P = \phi f_t$. Since $f_{1t} = \theta_{11}h_{1t}$, $f_{2t} = \theta_{21}h_{1t} + \theta_{22}h_{2t}$, and $f_{3t} = \theta_{31}h_{1t} + \theta_{32}h_{2t} + \theta_{33}h_{3t}$, we may examine the innovation propagation from the earlier SOP's to the later ones.

Finally, we make two assumptions on $\Sigma_\eta = E(\eta_t \eta_t')$ in order to examine dynamic responses of prices to shocks η_t.

Assumption 3. The permanent shocks η_{it} $(i = 1,\cdots,p-r)$ are uncorrelated.

Assumption 4. The permanent and transitory shocks are uncorrelated.

Thus, $\Sigma_\eta = \begin{pmatrix} \Sigma_{\eta^1} & 0 \\ 0 & \Sigma_{\eta^2} \end{pmatrix}$ is block diagonal (Assumption 4). Σ_{η^1} is diagonal (Assumption 3), so the common factors h_{it} $(i = 1,\cdots,p-r)$ are uncorrelated random walks.

We can now present the vector error correction model (VECM). Let the PPI stages $X_t = (x_{1t} \;\; \cdots \;\; x_{pt})'$ be I(1) and cointegrated with cointegration rank r. Then,

$$\Delta X_t = \mu + \Pi X_{t-1} + \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_k \Delta X_{t-k} + \varepsilon_t, \quad (2)$$

where Π and Γ_1 to Γ_k are $p \times p$, and ε_t is a $p \times 1$ vector white noise. The long-run impact matrix Π will have rank r, and can be expressed as $\Pi = \alpha\beta'$ for suitable $p \times r$ matrices α and β. X_t is non-stationary, ΔX_t is stationary, and the linear combinations given by $\beta' X_t$ are stationary.

We estimate the VECM in (2) following Johansen (1991), and then transform it to a vector moving average model

$$\Delta X_t = \mu + C(B)\varepsilon_t, \quad (3)$$

where $C(B)$ is a $p \times p$ matrix polynomial in the backshift operator B. To identify the common factor h_t, we rewrite (3) as

$$\Delta X_t = \mu + \Gamma(B)\eta_t, \quad (4)$$

where $\Gamma(B) = C(B)\Gamma_0$ and $\eta_t = \Gamma_0^{-1}\varepsilon_t$ for some nonsingular $p \times p$ matrix Γ_0. We choose Γ_0 so that (i) the $(p-r)$-vector η_t^1 represents innovations to the common stochastic trend with the partition $\eta_t = \left(\eta_t^{1\prime} \quad \eta_t^{2\prime}\right)'$, and (ii) $\Gamma(1) = \left(A \quad 0\right)$, with 0 being a $p \times r$ null matrix as $\Gamma(1)$ is of rank $(p-r)$. Then, using the well known expansion $\Gamma(B) = \Gamma(1) + \Delta\Gamma^*(B)$, (4) becomes

$$X_t = X_0 + \mu t + Ah_t + \Gamma^*(B)\eta_t,$$

which is the common trend model expressed in (1), denoting the stationary component $\Gamma^*(B)\eta_t$ by $\tilde{X}_t$.

The elements of A are the long-run multipliers of the permanent shock η_t^1, that is, $\lim_{n\to\infty} \partial X_t / \partial \eta_{t-n}^1$ because $h_t = \sum_{n=0}^{\infty} \eta_{t-n}$. The long-run multiplier of the transitory shock η_t^2 is zero because $\Gamma^*(B)$ is absolutely summable.

Under Assumption 1, the long-run multiplier A can be written as $\tilde{A}\Theta$ so that the permanent component is $X_t^P = Ah_t = \tilde{A}\Theta h_t$. Noting that $\beta' X_t$ should be stationary if X_t is cointegrated, $\beta' A = \beta' \tilde{A} = \mathbf{0}$. Thus, $\tilde{A}$ is chosen from $\hat{\beta}' \tilde{A} = \mathbf{0}$ where $\hat{\beta}$ is an estimate of β. For example, with $p = 4$ stages and $r = 1$, under Assumption 2 $\tilde{A}$ can be estimated with last row $\phi' = \left(-\hat{\beta}_1 \quad -\hat{\beta}_2 \quad -\hat{\beta}_3\right)$. The first permanent shock potentially affects all of the variables in X_t in the long run, the second potentially affects the second variable and those lower in the ordering, etc.

The approach of King et al (1991) for estimating the long-run multiplier A is followed. The first $(p-r)$ columns of $\Gamma(B)$ show how the series in ΔX_t respond to the permanent shocks η_t^1, and their accumulated sums show how the series in X_t respond to the permanent shocks. The response of x_{it} $(i = 1,\cdots,p)$ to each permanent shock $\eta_{j,t-n}$ occurring n periods ago is denoted by ${}_iR_j(n) = \partial x_{it} / \partial \eta_{j,t-n}$. It may be noted that we do not standardize a shock in order to make the ij^{th} elements of A the long-run multipliers of the permanent shock η_{jt}, i.e., $\lim_{n\to\infty} {}_iR_j(n)$.

Since the VECM can be used for forecasting, we also compute the fractions of the h-step ahead forecast error variance of $\Delta x_{i,t+h}$ $(i = 1,\cdots,p)$ attributed to each permanent shock η_{jt} $(j = 1,\cdots,p-r)$. The estimates provide information about the relative importance of permanent and transitory shocks in h-step ahead forecasts of ΔX_t.

4. Price Transmission among SOP's

The CSOP's have been generated back to 1947, while the ISOP's start in June, 1985. Thus, our analyses are carried out for the 11-year span, 6/85-5/96. All PPI and CPI series are core indexes, excluding Food and Energy. In addition, the CPI series excludes Used Cars. All series are monthly, seasonally adjusted, and in logarithms. In our empirical study the logarithms of all series are characterized as I(1) processes based on the augmented Dickey-Fuller (ADF) and Phillips-Perron tests. Some wage and CPI series display upward trends and their first differences show rather smoother series than PPI series. In other studies where wages and CPI series are used (e.g., Mehra, 1991), it is often found that the inflation series, the first difference of log prices, are I(1). However, it was not the case in our data, especially in PPI series which show clear mean-reverting in both ISOP and CSOP.

First, we examine results for the ISOP system. Lag length $k = 5$ in the VECM is chosen using the Akaike and Schwarz information criteria (AIC and SIC), as well as the battery of residual diagnostics. Table 3A reports the results of testing for cointegration. The ISOP series $X_t = (x_{1t}\ x_{2t}\ x_{3t}\ x_{4t})'$ are cointegrated with three common stochastic trends.

In Table 3B, following Johansen (1991), we test for weak exogeneity and for long-run exclusion. The latter test is based on the hypothesis that a subset of the variables in X_t do not enter the cointegration space, which, if not rejected, implies that the variables in

Table 3. ISOP

A. Testing for Cointegrating Rank (with k=5 lags)

H_0	*trace*	λ_{max}
$r = 0$	64.65**	46.21**
$r = 1$	18.44	13.11
$r = 2$	5.33	4.28
$r = 3$	1.06	1.06

B. Testing for H_0: $\alpha_i = 0$ and H_0: $\beta_i = 0$

i	H_0: $\alpha_i = 0$	H_0: $\beta_i = 0$
1	0.00013	0.00000
2	0.429	0.00000
3	0.00006	0.004
4	0.030	0.041

Table 4. CSOP

A. Testing for Cointegrating Rank (with k = 2 lags)

H_0	*trace*	λ_{max}
$r = 0$	47.88**	29.50**
$r = 1$	18.39*	15.58*
$r = 2$	2.81	2.81

** and * denote significance at 1% and 5% level

B. Testing for H_0: $\alpha_i = 0$ and H_0: $\beta_i = 0$

i	H_0: $\alpha_i = 0$	H_0: $\beta_i = 0$
1	0.952	0.001
2	0.010	0.00014
3	0.001	0.00031

Table 5. Fractions of Forecast Error Variances

A. ISOP

		Stage			
shock	h forecast horizon	i=1	i=2	i=3	i=4
η_1	1	.805	.487	.051	.000
	2	.818	.708	.453	.025
	3	.788	.719	.455	.028
	6	.840	.762	.472	.255
	12	.861	.770	.452	.300
	60	.848	.774	.451	.305
η_2	1	.014	.265	.581	.161
	2	.043	.106	.258	.150
	3	.063	.104	.260	.160
	6	.041	.075	.245	.166
	12	.035	.069	.241	.155
	60	.038	.066	.241	.255
η_3	1	.040	.017	.218	.749
	2	.040	.011	.093	.695
	3	.059	.012	.093	.685
	6	.073	.038	.104	.482
	12	.068	.058	.137	.454
	60	.082	.065	.140	.452

B. CSOP

	Shock					
	η_1			η_2		
h	$i = 1$	$i = 2$	$i = 3$	$i = 1$	$i = 2$	$i = 3$
1	.972	.042	.000	.028	.619	.484
2	.946	.161	.004	.023	.601	.451
3	.941	.206	.005	.025	.575	.455
6	.941	.326	.011	.026	.490	.457
12	.940	.423	.015	.027	.417	.457
60	.938	.456	.016	.028	.392	.456

question can be omitted from the long-run relations between the ISOP's. The hypothesis is $H_0: \beta_i = 0$ for i=1 to 4. The results show that all of them are significant. Similar tests have been performed on the rows of α, corresponding to tests for weak exogeneity. They can be formulated as $H_0: \alpha_i = 0$ for each i=1 to 4, that the i^{th} component in X_t is not adjusting toward the estimated long-run relations. If not rejected, it implies that the variable in question itself takes the role of a common trend in the system.

From Table 5A, it is observed that the first permanent shock η_1, the permanent shock to the Crude stage, explains a significant portion of the inflation fluctuations in all stages, the amount declining through the stages, but increasing in the long run (as the forecast horizon h increases). The second permanent shock η_2, which is another permanent shock to Primary, accounts for substantial variations in Primary and Semifinished in the short run. Its role declines for the longer forecast horizons. The third permanent shock η_3 that arrives at the third stage of processing shows very significant inflation transmission from Semifinished to Finished.

Turning to Figure 1, which graphs the dynamic responses to the three shocks along with the two standard deviation confidence bands computed by Monte Carlo simulation using 300 replications (dashed lines), we see significant long-run effects of the first shock on Primary, the second shock on Semifinished, and the third shock on Finished. None of the other effects in the forward direction appear significant. In the backward direction, some of the short-run effects are substantial, implying that demand shocks matter in the short run. However, their long-run effects are zero by construction.

To sum up, ISOP exhibits inflation transmission through the stages very strongly, with significant one-step forward flow. The multi-step forward transmissions are insignificant. An alternative bivariate model with Finished and Input to Finished indicates cointegration. The latter index is intended to reflect the appropriate contribution of the previous stages to Finished.

Table 4, Table 5B, and Figure 2 present the results for CSOP. Depending on the significance level chosen, the Johansen tests suggest r=1 or 2. Here, we proceed with r=1 and two common factors. The error correction coefficients are all significant except α_1. Its non-significance indicates that Crude PPI does not adjust toward the estimated long-run relations, that Crude takes the role of a common trend in the system. The impulse responses in Figure 2 show a strong, fairly rapid response of Crude and Primary, but not Finished, to the first permanent shock. Finished responds rapidly to the second permanent shock. Similarly, the variance decomposition statistics (Table 5B) show that the first permanent shock strongly influences the first two stages and the second permanent shock influences stages 2 and 3. In general, the results for CSOP are similar to those for ISOP, showing significant inflation transmission through the three stages. The multi-step forward transmission is insignificant.

5. Price Transmission to the CPI

We next examine the results of adding the CPI to both ISOP and CSOP systems. Space limitations prevent including the tables corresponding to Tables 3-5. For the system consisting of the ISOP and the CPI, cointegration is present, but the cointegrating rank is still 1, and the CPI does not enter the cointegrating relationship significantly. Overall, all permanent shocks except the first have a sizable long-run impact on the CPI, most rapidly for the fourth shock.

For the CSOP plus the CPI, the cointegration test statistics are unclear. Given that the CSOP system appears to have cointegrating rank either 1 or 2, it is reasonable to examine results for these values. With rank 2, an interesting picture emerges that one cointegrating vector relates Finished and the CPI alone. The other cointegrating vector can be formulated among the three CSOP stages. Confirmation for this comes from independent testing for cointegration for the pair Finished and the CPI. Figure 3 looks similar to Figure 2 for the three CSOP stages. The CPI responds strongly to the second shock, but not the first.

CSOP Finished relates more closely to the CPI than ISOP Finished. The latter pair has slightly inferior cointegration test statistics, and the entire ISOP output system relates less strongly to the CPI.

A key criterion for usefulness of time series models is forecast performance. Our evaluation of CPI forecasts from the SOP's proceeds as follows. The VECM's are estimated for ISOP plus CPI (with p=5, k=5, and r=1), and CSOP plus CPI (with p=4, k=2, and r=2) using the observations up to 3, 4, and 5 years prior to 5/96, obtaining post-samples of size 36, 48, and 60, respectively. Based on the estimated models, one-step ahead forecasts are generated for those post-samples, and mean square error (MSE) and mean absolute error (MAE) losses are calculated. The sign test, the Wilcoxon signed-rank test, and tests of Granger & Newbold, Meese & Rogoff, and Diebold & Mariano are all computed. Diebold & Mariano (1995) describes and discusses the performance of all these tests. Since the CPI has grown fairly slowly and steadily over most of the last decade, great differences cannot be expected. Still, for all three post-samples, CSOP forecasts have smaller loss, with some tests achieving significance at the 5% level.

Thus, our results seem to favor the CSOP over the ISOP system in terms of explaining the CPI. These results, however, are based on ISOP output indexes only. When we form a system with the series Input to Final Demand added to the ISOP output indexes and the CPI, forecast error loss is sometimes smaller for CSOP, sometimes for ISOP, depending on the post-sample and the loss criterion, with the differences not significant whichever test statistic is used. Input to Final Demand from the ISOP is closely related to the CPI, similar to CSOP Finished.

6. Conclusions

Using the vector error correction models (VECM), the sources of inflation and its transmission (direction, speed, and magnitude) are examined. We show how the cointegration restriction can be used to identify common stochastic trends and how we may investigate the system's responses to the permanent shocks. Two BLS stage of processing (SOP) systems are compared. Forecasts of CPI inflation using the two SOP systems are evaluated.

The results on the cointegrating relations, on the response to shocks, and on the forecast error variance decomposition all give support to Popkin's original notion of stages. Later stages respond to earlier stages, and the CPI responds to Finished Goods. In the CSOP, separating out Finished is beneficial, since it is less volatile than Crude or Intermediate, and similarly for the ISOP. By a small margin, CSOP outperforms the four output ISOP indexes in post-sample forecasts of the CPI.

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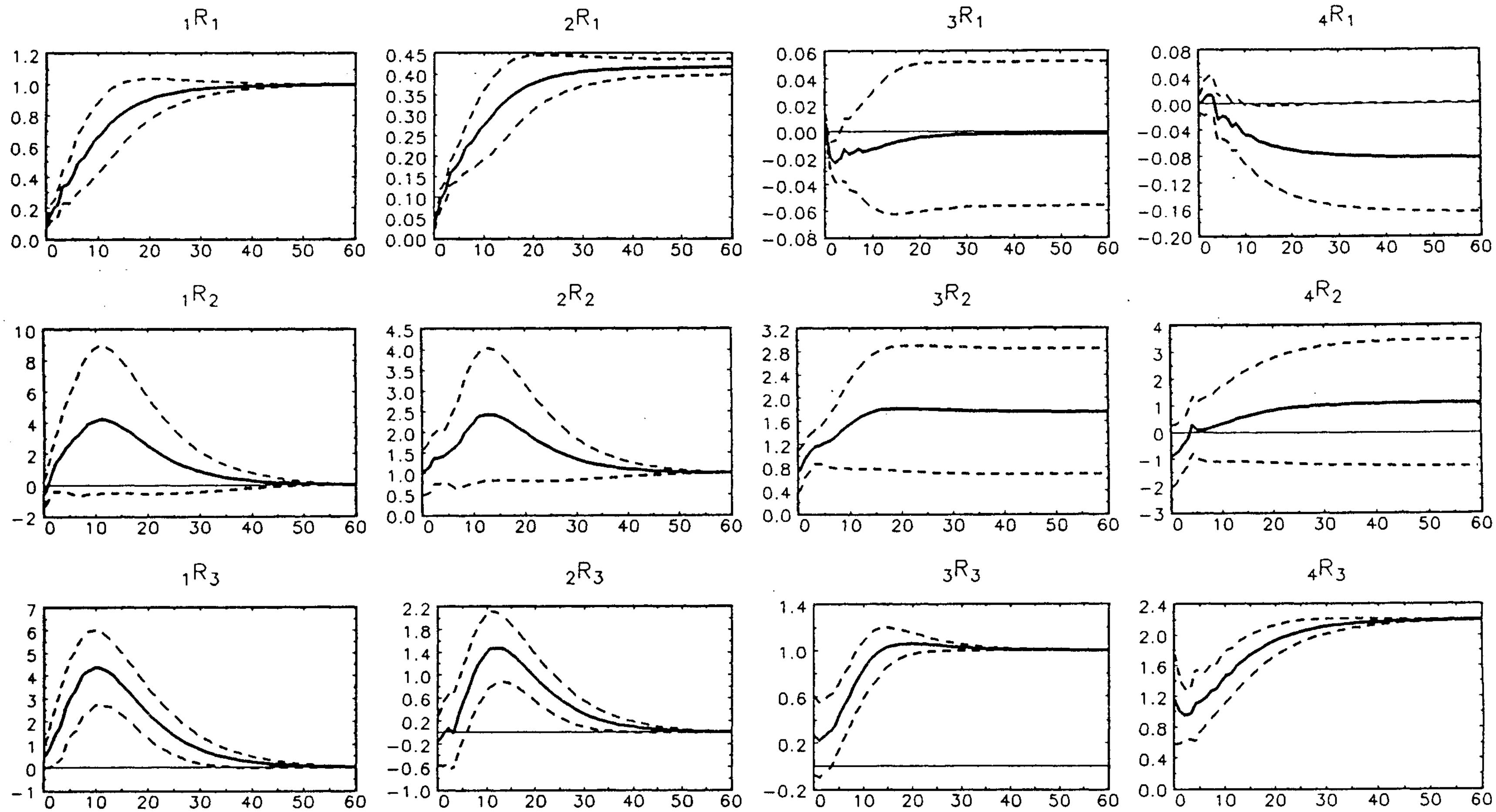

Figure 1. ISOP

Responses ($_iR_j$) of variable x_i to shock η_j

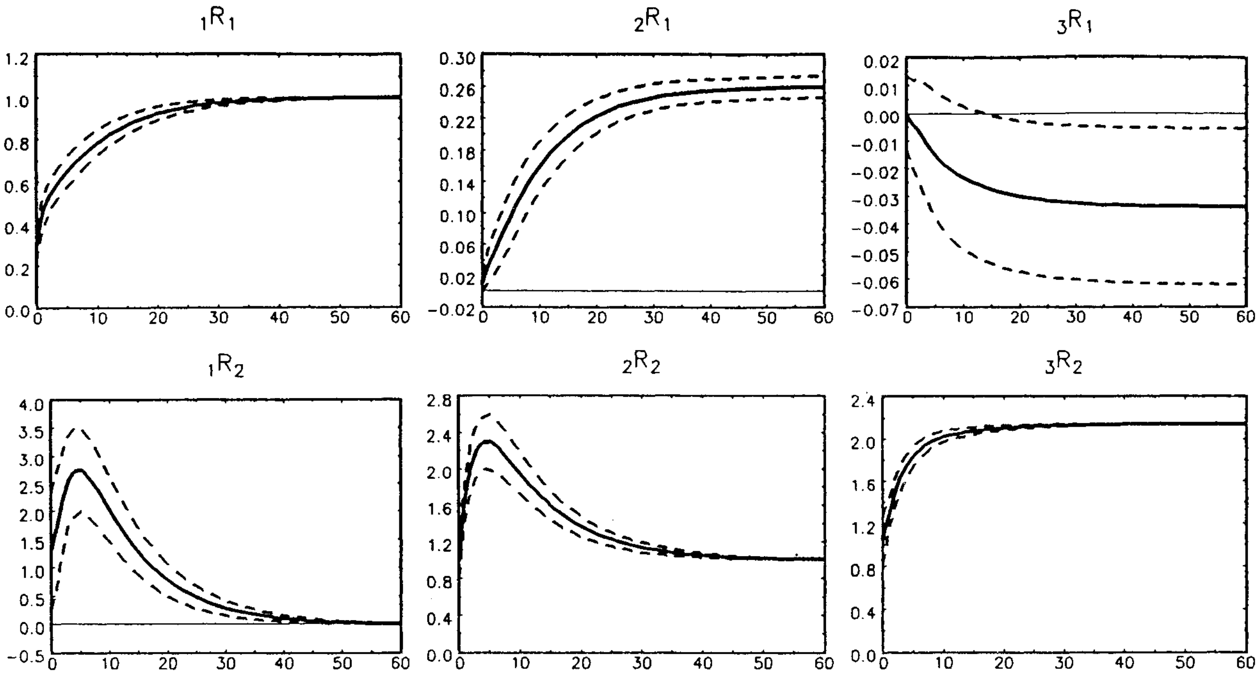

Figure 2. CSOP

Responses ($_iR_j$) of variable x_i to shock η_j

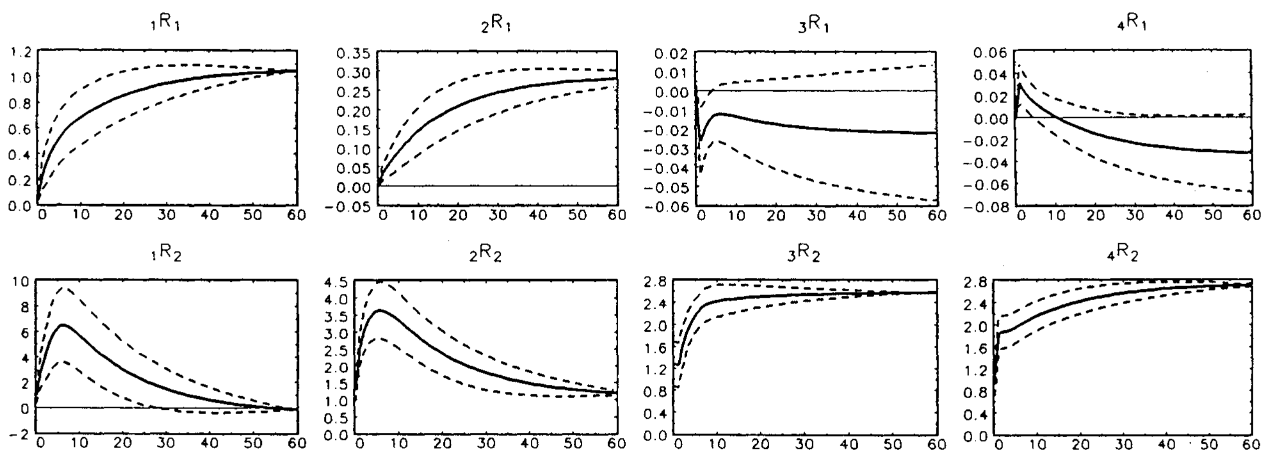

Figure 3. CSOP plus CPI

Responses ($_iR_j$) of variable x_i to shock η_j