The Dynamic Inflationary Effects of Permanent and Transitory Energy Price Shocks

By

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Abstract:

We provide new econometric evidence on the inflationary effects of energy price shocks. A novel aspect of our approach is that we use a permanent-transitory (P-T) decomposition to separate shocks into permanent effects due to long-run changes in underlying economic fundamentals, versus transitory effects that represent only short-run temporary disturbances to long-run equilibrium relationships. We find that the P-T decomposition provides some interesting new insights into the inflationary effects of energy price shocks. In particular, only permanent shocks are inflationary while transitory shocks have very little effect on the CPI or PPI. We explain this phenomenon in terms of the follow through effect of energy price shocks on other prices. If energy price changes are perceived as permanent then other consumer and producer prices respond which leads to permanent changes in the underlying price indexes. But if a shock is perceived to be transitory other consumer and producer prices do not respond and there is little impact on the underlying price indexes.

Keywords: energy prices, inflation, permanent-transitory decomposition

JEL Codes: Q02, Q11, O13

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1. Introduction

Energy prices have an important dynamic relationship with inflation for two main reasons. First, energy price changes affect consumer and producer price indexes directly because energy prices have a significant weight in the construction of broader price indexes. Second, in addition to this direct relationship there is also an indirect effect as energy price changes feed through into changes in other prices that make up the indexes. Both of these pathways may be dynamic as future prices of many different goods and services each respond to current and past energy price changes, and energy prices may respond to current and past changes in price indexes. Therefore, it can be difficult disentangle the true dynamic relationship between energy price changes and current and future changes in aggregate price indexes, such as the consumer price index (CPI) and producer price index (PPI).

The nature of the relationship between energy prices and general measures of inflation is important because it characterizes the inflationary effects of energy price shocks, as well as the effect that inflation in the general price level can have on energy prices. Since managing inflation is an important macroeconomic policy goal, knowledge of the relationship between energy prices and the CPI and PPI can inform strategies for responding to the inflationary effects of energy price shocks. An understanding of the role of energy price shocks may also be used to forecast the effects that particular types of shocks, such as those brought about by an expansion of U.S. biofuel production, or the expansion and contraction of U.S. shale oil production, will have on movements in the general price level.

The most common theoretical explanation for a positive relationship between energy prices and inflation is a classic supply-side effect. Rising energy prices indicate an increase in energy scarcity and, because energy is a basic input into production, aggregate output falls putting upward pressure on the general price level. Early empirical studies found strong evidence of a negative relationship between energy prices and output growth (see Hamilton, 1983 for a seminal contribution and summary of earlier literature; and Brown and Yücel 2002 for a more recent summary and review). More recently, attention has turned to investigating the relationship between energy prices and inflation more directly, in most cases finding strong evidence of a significant positive relationship (e.g., Hooker, 2002; Cunadoa, and Perez de Gracia, 2005; Ewing and Thompson, 2007 and Cologni and Manera, 2008). Asymmetries in the dynamic relationship between energy prices and economic activity have also been investigated, with some evidence suggesting that the intensity of the relationship has declined over time (e.g., Lardic and Mignon, 2008).

In this paper we provide new econometric evidence on the inflationary effects of energy price shocks. A novel aspect of our approach is that we use a permanent-transitory (P-T) decomposition to separate shocks into permanent effects due to long-run changes in underlying economic fundamentals, versus transitory effects that represent only short-run temporary disturbances to long-run equilibrium relationships. We find that the P-T decomposition provides some interesting new insights into the inflationary effects of energy price shocks. In particular, only permanent shocks are inflationary while transitory shocks have very little effect on the CPI or PPI. We explain this phenomenon in terms of the follow through effect of energy price shocks on other prices. If energy price changes are perceived as permanent then other consumer and producer prices respond which leads to permanent changes in the underlying price indexes. But if a shock is perceived to be transitory other consumer and producer prices do not respond and there is little impact on the underlying price indexes. Therefore, distinguishing between permanent and transitory shocks has important implications for how we perceive and understand the inflationary effects of energy price changes.

2. Empirical Approach

A price index I_t (e.g., the CPI) will depend on the *m* prices that make up the index, which we represent generally as:

(1) $$I_t = f(P_{1t}, P_{2t}, ..., P_{mt}).$$

The indexes are calculated based on weighted changes in the underlying prices from a base period in which the index is normalized to 100.[1] The prices included in the calculation are based on a representative basket of the underlying consumer or producer goods and services. To construct the change in the index, price changes for component goods and services are weighted according to their importance (expenditure or cost share) for the underlying representative population.[2] Energy prices typically play a prominent role in both CPI and PPI construction because they have significant expenditure and cost share weights in the underlying representative basket of goods and services.

Because of the way the indexes are constructed, the functional relationship represented in (1) will depend implicitly on price levels in the base year as well as the expenditure weights used to construct the index. It is important to remember, however, that because CPI and PPI indexes are constructed using price changes of specific products, there is no way to directly ascertain the

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[1] A detailed methodological description is available in the Bureau of Labor Statistics Handbook of Methods, at http://www.bls.gov/opub/hom/.

[2] For the CPI underlying prices are collected each month in 87 urban areas across the U.S. from about 4,000 housing units and approximately 26,000 retail establishments-department stores, supermarkets, hospitals, filling stations, and other types of stores and service establishments. For the PPI price data are provided by firms on a voluntary basis. The Bureau of Labor Statistics strongly encourages cooperating companies to supply actual transaction prices at the time of shipment to minimize the use of list prices. Prices submitted by survey respondents are effective on the Tuesday of the week containing the 13th day of the month.

impact of a particular price change (say for energy products) on the prices of other goods or services that make up the index. Furthermore, expenditure and costs weights are recalculated annually making it difficult to isolate the effects of energy price changes directly from the formula used to calculate the index. Given these problems we take a reduced form time series approach to investigating the dynamic relationship between energy price changes and changes in the general price level.

The dimensionality of *m* in the index formulas (1) is usually large making full dynamic analysis involving the index and all of the relevant prices impractical. The approach we take is to consider a reduced dimension log-linear approximate relationship between the index and a subset of prices:[3]

$$(2) \qquad ln\, I_t = \beta_0 + \sum_{j=1}^{n-1} \beta_j \, ln\, P_{jt} + e_t$$

where e_t is a random error and *n* is considerably smaller than *m*. Because there are many relevant prices missing from (2) we interpret the relationship a reduced form whose β's encompass the indirect effect of changes in the P_j's on all of the other prices not included in the reduced dimension system. Similarly, since e_t will include the random effects of missing prices all of the variables in (2) should be treated as endogenous.

For econometric modeling each of the variables in (2) could be integrated of order zero, denoted I(0), or integrated of order one, denoted I(1). However, previous studies and the evidence presented below suggest that both the indexes and prices we include in our analysis can be modeled as I(1). In this case it follows that there could be cointegrating (i.e., long-run equilibrium) relationships among the variables in the reduced dimension system (2). If all variables are I(1) a

[3] Log transformations are commonly used in price modeling because they are consistent with the statistical properties of most price data and facilitate interpretation of coefficients in terms of proportional relationships between prices.

maximum of n-1 cointegrating relationships are possible among the n variables in the system (n-1 log prices plus the log index). Because the system is reduced dimension it is also possible that (2) itself is not a cointegrating relationship, in which case the error term e_t would be I(1).

To complete the system we add equations for each of the log prices included in (2). In specifying these equations we want to allow for the possibility of long-run cointegrating relationships among variables in the system, as well as for rich dynamics in the interactions between the prices and the index. A convenient way of accomplishing these goals is to represent the system as a vector error correction (VEC) model. In matrix form the VEC models the n-vector $\mathbf{y}_t = (ln\,P_{1t}, ln\,P_{2t}, \ldots, ln\,P_{n-1,t}, ln\,I_t)$ as:

$$(3) \qquad \Delta \mathbf{y}_t = \boldsymbol{\mu} + \boldsymbol{\alpha}\,\mathbf{z}_{t-1} + \sum_{i=1}^{q} \boldsymbol{\Gamma}_i \Delta \mathbf{y}_{t-i} + \boldsymbol{\varepsilon}_t$$

where $\mathbf{z}_{t-1} = \boldsymbol{\beta}'\,\mathbf{y}_{t-1}$ is the (r x 1) vector of lagged equilibrium errors from the r cointegrating relationships; $\boldsymbol{\beta}$ contains the cointegrating vectors representing long-run equilibrium relationships between the variables; the $\boldsymbol{\mu}$, $\boldsymbol{\alpha}$, and $\boldsymbol{\Gamma}_i$'s are unknown parameters to be estimated, q is the lag order for the dynamics; and the VEC errors $\boldsymbol{\varepsilon}_t$ are serially uncorrelated but may be contemporaneously correlated. The advantages of the VEC representation for our application are that it is straightforward to estimate using Johansen's maximum likelihood methods, it treats all variables as endogenous, it allows for I(1) and cointegrated variables, and it also allows for rich dynamics in the way that the prices and the index interact with one another over time.

The VEC errors $\boldsymbol{\varepsilon}_t$ represent unpredictable shocks to the variables in the system but analyzing and interpreting the effects of these shocks is hampered because they are contemporaneously correlated and represent the joint effects of many different fundamental influences on the prices and price index. To provide a structural interpretation of the effects of different shocks we need to impose additional identification assumptions. The conventional way of solving this problem is to orthogonalize the shocks and impose a recursive ordering, leaving the dynamics of the system unrestricted. This approach to identification in VEC models is now standard and will not be discussed further here (see, for example, Hamilton 1994).

A disadvantage of the conventional recursive approach to identification for our purposes is that it produces orthogonalized structural shocks that remain mixtures of permanent and transitory effects. It is therefore incapable of decomposing shocks into those that have permanent effects and those that have transitory effects, and therefore incapable of identifying separate long-run and short-run dynamic relationships between the prices and the index. To overcome this problem we follow Gonzalo and Ng (2001) and impose an alternative identification scheme that decomposes $\boldsymbol{\varepsilon}_t$ into orthogonal permanent and transitory shocks. The dynamic effects of the resulting permanent and transitory shocks can then be simulated to evaluate the effects of both types of shocks on the path of prices and the index.

To motivate the alternative identification approach consider the matrix $\mathbf{G} = [\boldsymbol{\alpha}_{\perp}, \boldsymbol{\beta}]'$ where $\boldsymbol{\alpha}_{\perp}'$ (defined by $\boldsymbol{\alpha}_{\perp}'\boldsymbol{\alpha} = \boldsymbol{0}$) is the orthogonal complement of the speed of adjustment parameters $\boldsymbol{\alpha}$ from the VEC; and $\boldsymbol{\beta}'$ is the matrix of cointegrating vectors. Transforming the VEC model (3) using $\boldsymbol{G}$ gives:

$$(4) \qquad \mathbf{G}\Delta\mathbf{y}_t = \mathbf{G}\boldsymbol{\mu} + \mathbf{G}\boldsymbol{\alpha}\,\mathbf{z}_{t-1} + \mathbf{G}\sum_{i=1}^{q}\boldsymbol{\Gamma}_i\Delta\mathbf{y}_{t-i} + \mathbf{G}\boldsymbol{\varepsilon}_t\ .$$

By construction, the first $n - r$ rows of $\boldsymbol{G}$ eliminate the lagged equilibrium errors $\mathbf{z}_{t-1}$ from the first $n - r$ equations, causing these equations to be specified in terms of differences only. Also by construction, the remaining r rows of $\boldsymbol{G}$ form I(0) linear combinations of the $\mathbf{y}_t$ vector at all lags which causes the remaining r equations to depend on stationary linear combinations only. The result is that the transformed errors $\mathbf{u}_t = \mathbf{G}\boldsymbol{\varepsilon}_t$ form a P-T decomposition with the first *n* - *r* rows being permanent shocks and the remaining *r* rows being transitory shocks. We can interpret the permanent shocks as unpredictable shocks to the *n* – *r* fundamental common factors (or "common trends") driving the long-run equilibrium values of variables in a cointegrated system (see Stock and Watson, 1988; Gonzalo and Granger, 1995; Proietti, 1997; and Hecq, Palm, and Urbain, 2000). The transitory shocks can be interpreted as temporary deviations from the *r* long-run equilibrium relationships that correct themselves over time (i.e., shocks to the equilibrium errors $\mathbf{z}_t$).

To facilitate analyzing the effects of shocks we write the VEC model (4) explicitly in terms of the permanent and transitory shocks:

$$(5) \qquad \Delta\mathbf{y}_t = \boldsymbol{\mu} + \boldsymbol{\alpha}\,\mathbf{z}_{t-1} + \sum_{i=1}^{q}\boldsymbol{\Gamma}_i\Delta\mathbf{y}_{t-i} + \mathbf{G}^{-1}\mathbf{u}_t \,.$$

In principle we could use (5) to trace out the dynamic effects of permanent and transitory shocks to the system. However, this task is complicated by the fact that although $\mathbf{u}_t$ is a P-T decomposition the elements of $\mathbf{u}_t$ will generally be contemporaneously correlated. Gonzalo and Ng (2001) suggest solving this problem by imposing a recursive ordering on the permanent and transitory shocks. To accomplish this consider a matrix **H** such that $\mathbf{u}_t = \mathbf{H}\mathbf{v}_t$ where $\mathbf{v}_t$ is a vector of orthogonal "structural" permanent and transitory shocks with unit variance. Cointegration requires that **H** be lower block triangular (transitory shocks cannot contemporaneously influence permanent shocks, otherwise they would not be transitory; see Gonzalo and Ng, 2001). If we further impose a recursive ordering among the permanent shocks (permanent components of $\mathbf{v}_t$ only influence permanent $\mathbf{u}_t$ shocks ordered equal or lower in the system) and a recursive ordering among the transitory shocks (transitory components of $\mathbf{v}_t$ only influence transitory $\mathbf{u}_t$ shocks ordered equal or lower in the system), then **H** is lower triangular and satisfies $\mathbf{HH}' = Cov(\mathbf{u}_t) = \mathbf{G}\,Cov(\boldsymbol{\varepsilon}_t)\,\mathbf{G}'$.

The matrix **H** can be estimated by computing the Cholesky decomposition of $\widehat{\mathbf{G}}\,Cov(\widehat{\boldsymbol{\varepsilon}}_t)\,\widehat{\mathbf{G}}'$ where $\widehat{\mathbf{G}}$ and $Cov(\widehat{\boldsymbol{\varepsilon}}_t)$ are estimated using the VEC model (3).

The complete P-T decomposition defined on orthogonalized shocks with unit variance is given by:

$$(6) \qquad \Delta\mathbf{y}_t = \boldsymbol{\mu} + \boldsymbol{\alpha}\,\mathbf{z}_{t-1} + \sum_{i=1}^{q}\boldsymbol{\Gamma}_i \Delta\mathbf{y}_{t-i} + \mathbf{G}^{-1}\mathbf{H}\mathbf{v}_t$$

where, as before, $\mathbf{z}_{t-1} = \boldsymbol{\beta}'\mathbf{y}_{t-1}$. All components of this model can be estimated from the VEC estimation form (3). After estimation, (6) can then be used to simulate the dynamic effects of the different permanent and transitory shocks on each of the $\mathbf{y}_t$ variables. Results can be displayed as impulse response functions (IRFs). For some purposes it will also be useful to decompose the forecast error variance of the $\mathbf{y}_t$ variables into components due to permanent versus transitory shocks (FEVD). By construction, the first $n - r$ elements of $\mathbf{v}_t$ will be orthogonal permanent shocks and the last r elements will be orthogonal transitory shocks. IRF and FEVD results may be sensitive to the ordering of shocks within each category (permanent and transitory), but the application can often provide guidelines on what ordering makes sense (essentially a just-identifying assumption). In the application below we show how a particular recursive ordering can be interpreted in terms of structural permanent and transitory shocks.

It is also important to note that orthogonalization of the permanent and transitory shocks via Cholesky decomposition does *not* preclude certain shocks from influencing some variables in $\mathbf{y}_t$ contemporaneously (unlike in conventional recursive VECs). This is because in conventional Cholesky decomposition $\mathbf{G}^{-1}$ is an identity matrix but under the P-T decomposition this matrix can transmit orthogonal permanent and transitory shocks contemporaneously to all variables in the system. In this sense the P-T recursive structure is not as rigid as the conventional recursive structure typically applied in structural VEC analysis.

3. Variables and Data

In this paper we consider several trivariate VEC models, each including two energy prices and one index. The two energy prices are the price of gasoline and the price of ethanol. Gasoline is included because it is arguably the most important energy price in the determination of both consumer and producer prices, and because it is highly correlated with other important energy prices, such as the price of crude oil and diesel. Ethanol is included because one of the goals of this study is to investigate the effects of permanent and transitory shocks to ethanol prices, such as those that may be associated with expansion of the role of biofuels in the U.S. economy. The application is to U.S. data.

Three different price indexes are studied with separate trivariate models estimated for each index.[4] The first index is topline CPI which is the most inclusive measure of the general level of consumer prices. The second index is the energy CPI which is investigated to see if results differ when the price index is more directly dependent on the gasoline and ethanol prices included in the analysis. The third and final index used is the topline PPI which is investigated to see if results differ markedly for producer price indexes versus consumer price indexes. We also investigated models using the energy component of the PPI but results are similar to those using the energy component of the CPI and so are not reported here. Furthermore, we investigated models using CPI and PPI excluding energy but results were virtually identical to those for topline CPI and PPI

[4] Higher dimensional models with multiple indices (and additional energy prices) included could have been investigated but the high correlation between indices, and between many energy prices, makes estimation and interpretation of higher order models more difficult. We find useful insights can be obtained even when limiting ourselves to trivariate models.

and so are not reported here either. All models are estimated using monthly data from January 1990 to June 2014.

Gasoline prices are regular gasoline spot price, FOB New York Harbor $/gallon. Ethanol prices are the average ethanol rack price, FOB Omaha, Nebraska in $/gallon. Both prices are plotted monthly in Figure 1. There is clearly a close connection between the two prices suggesting a long-run equilibrium relationship exists between them. However, gasoline prices appear to have risen relative to ethanol prices over time, particularly since 2005.

Topline CPI is the U.S. city average CPI for all items with 1982-84 = 100 and the energy CPI is the U.S. city average CPI for all energy prices, again with 1982-84 = 100. Year over year monthly changes in each of these indexes are plotted monthly in Figure 2. For completeness we also show year over year changes in the CPI for all items less energy. The CPI for all items less energy follows topline CPI closely and P-T decomposition results are very similar using either of these indexes. Therefore only P-T decomposition results for topline CPI are reported here. As expected, the energy CPI is much more volatile than topline CPI.

Topline PPI is the PPI for all industrial commodity items with 1982 = 100. Year over year monthly changes are plotted in Figure 3. For completeness we also include year over year changes in the energy PPI (PPI for fuels and related products and power, 1982=100) and the PPI for all items less energy (PPI, for all industrial commodities less fuels, 1982=100). Topline PPI is clearly more volatile than topline CPI because producer goods depend relatively more on material goods in the supply chain which tend to vary more than consumer good prices. The PPI for all items less energy follows topline PPI closely and P-T decomposition results are very similar using either index, so only results for topline PPI are reported here. The energy PPI is much more variable than topline PPI, as expected. However, P-T decomposition results using the energy PPI were very similar to those using the energy CPI as the price index, so only the latter results are reported here.

All of the variables included in the analysis were transformed using logarithms and tested for unit roots using the augmented Dickey-Fuller, Phillips-Perron, and Dickey-Fuller GLS test with trend. Results are reported in Table 1 and provide support for the hypothesis that all series are I(1), possibly with drift. These findings are consistent with considerable existing evidence.

We also tested for cointegration among variables in each of the trivariate models estimated using Johansen trace tests. Results are reported in Table 2 and support two cointegrating relationships (one single common factor is driving the permanent component of all series) in each model. Hence, VECs with two cointegrating vectors are estimated for each trivariate model.

4. Results for Energy Prices and the CPI

We begin with a trivariate model that includes gasoline price (PGAS), ethanol price (PETH), and topline CPI (CPI). Lag length selection criteria (FPE and AIC) support two lagged differences in the VEC (i.e., $q = 2$) and a joint LM test for no autocorrelation in the residuals of the 2 lag model cannot be rejected (p-value = 0.167 against first order autocorrelation and 0.403 against second order autocorrelation). Full VEC results are of little intrinsic interest by themselves and so are not reported. However, results for the two cointegrating vectors ($\boldsymbol{\beta}$ matrix) estimated using Johansen's maximum likelihood method are:

(7a) $$ln(CPI_t) = 5.214 + \underset{(9.91)}{0.231} ln(PGAS_t)$$

(7b) $$ln(PETH_t) = 0.400 + \underset{(17.32)}{0.490} ln(PGAS_t)$$

where numbers in parentheses are consistent t-statistics. Two cointegrating vectors imply a single I(1) common factor, so there is a single permanent shock driving the long run equilibrium values of all three series. We interpret this factor as a common economic fundamental that drives permanent changes in energy prices and the CPI. When a shock to the common factor increases long-run equilibrium (permanent) gasoline price by 1% the cointegration results suggest a corresponding long-run equilibrium CPI increase of 0.23% and a long-run equilibrium ethanol price increase of 0.49%. Hence, a permanent 1% increase in gasoline prices will eventually be associated with permanent increases in both ethanol prices and the CPI, although the proportional CPI (ethanol price) increase is only about one quarter (one half) of the proportional gasoline price increase. This long-run CPI change is much higher than would be suggested by simply looking at the expenditure weight on gasoline price in the CPI, which for 2007-2008 was around 5% (i.e., would suggest a 1% gasoline price increase would be associated with just a .05% increase in the CPI, holding other prices constant). The difference is because the VEC model allows other prices (and future gasoline prices) to respond dynamically to any current gasoline price shocks (i.e., is a long-run relationship that allows other prices to change and respond).

Because there are two cointegrating vectors and one permanent shock there are two transitory shocks, one representing shocks to the first long-run equilibrium relationship (7a) between gasoline price and the CPI and one representing shocks to the second long-run equilibrium relationship (7b) between gasoline and ethanol prices. It will be shown below that neither transitory shock influences the CPI significantly so a transitory shock to the first long-run equilibrium relationship (7a) is tantamount to a transitory gasoline price shock. Because the gasoline market is much larger than and dominates the ethanol market, we order this transitory gasoline price shock first in the recursive order. Therefore, transitory gasoline price shocks are allowed to spill over contemporaneously into the ethanol market. This leaves the orthogonal shock to the ethanol-gasoline price relationship (7b) ordered second, which excludes it from contemporaneously influencing the gasoline price-CPI relationship. This provides a natural interpretation for the second transitory shock as an ethanol price shock.

We used these identification assumptions, along with estimates from the VEC, to compute IRFs for each of the three shocks by simulating the decomposition (6) starting from an initial point of long-run equilibrium. The system is then perturbed with a one-time change to one of the orthogonal shocks and the resulting dynamic time path for all variables is computed. Then the simulation is repeated sequentially for each of the orthogonal permanent and transitory shocks. Graphs of the resulting IRFs are provided in Figures 4-6. The size of the permanent shock (Figure 4) is normalized so that it eventually increases gasoline price by 1% (see the convergence point for the gasoline price response in the figure). To be consistent with the cointegration estimation results the long-run effect on ethanol price and the CPI should then be a 0.49% and 0.23% increase, which is evident in the figure (see the respective convergence points for ethanol price and the CPI). Notice, however, that the dynamic response pattern of energy prices to the permanent shock is quite different to that of the CPI. The initial energy price responses overshoot their long-run equilibrium value and then converge slowly back to it. In contrast, the CPI adjusts almost immediately to its new long-run equilibrium value and then stays there. Hence, the inflationary impact of a permanent shock is almost immediate.

The effect of the transitory gasoline price shock (Figure 5) is normalized so the immediate contemporaneous impact of the shock is to increase gasoline price by 1%. Gasoline prices then remain above their long-run equilibrium relationship with the CPI for many months. Indeed, it takes about 12-18 months before half of the adjustment back to long-run equilibrium levels occurs. Eventually, however, the effect of the transitory shock does dissipate. The positive transitory gasoline price shock also increases ethanol prices temporarily but by proportionately less than gasoline prices. The dynamic adjustment of ethanol prices back to their long-run equilibrium relationship then follows a similar pattern to gasoline prices (see Figure 5). However, the transitory gasoline price shock has virtually no effect on the CPI. Hence, while transitory gasoline price shocks spill over into ethanol prices they have virtually no effect on the CPI. Indeed, FEVD results show that 93% of the unpredictable variation in CPI is due to the permanent shock with only 7% due to transitory shocks. In contrast, 35% of the unpredictable variation in gasoline prices is due to temporary gasoline price shocks.

The effect of the transitory ethanol price shock (Figure 6) is normalized so the immediate contemporaneous impact of the shock is to increase ethanol price by 1%. Remembering this shock is a shock to the long-run equilibrium relationship between ethanol and gasoline prices, the latter respond immediately with a small proportional decline. However, the effects of the transitory ethanol price shock on both ethanol and gasoline prices dissipates much more rapidly than the effects of a transitory gasoline price shock on these same energy prices. Furthermore, the transitory ethanol shock has virtually no effect on the CPI and little effect on gasoline prices (see Figure 6). Consistent with this result, FEVD results suggest that 84% of the unpredictable variation in ethanol price is due to transitory ethanol price shocks.

Overall, the IRF results suggest shocks that permanently increase gasoline prices also permanently increase ethanol prices and the CPI, but by smaller proportions (about one half and one fourth, respectively). On the other hand, the CPI responds minimally to temporary gasoline or ethanol price increases. A possible explanation for these results is that permanent energy price increases permeate through the economy and affect all of the prices that make up the CPI, therefore having a significant but subdued effect on the CPI. On the other hand, energy price shocks which are viewed as transitory do not transmit to other prices in the economy and therefore have little effect on the CPI, even in the short run.

5. Results for Energy Prices and the Energy CPI

Next we analyze a second trivariate model that includes the same energy prices--gasoline and ethanol--but uses the energy component of the CPI (CPIEN). We want to investigate if results and conclusions are different if we use a price index that is more dependent on the underlying energy prices. Lag length selection criteria again support two lagged differences in the VEC (i.e., q = 2) and there is no evidence of residual autocorrelation from this model. Results from estimating the two cointegrating vectors are:

(8a) $$\underset{}{ln(CPIEN_t) = 4.940 + \underset{(21.29)}{0.534}\, ln(PGAS_t)}$$

(8b) $$ln(PETH_t) = 0.441 + \underset{(14.19)}{0.467}\, ln(PGAS_t)$$

where numbers in parentheses are again consistent t-statistics. Two cointegrating vectors implies a single I(1) common factor, so there is a single permanent shock driving the long run equilibrium values of all three series. A shock to the common factor which permanently increases long-run gasoline price by 1% will also increase long-run equilibrium ethanol price by 0.47% and long-run equilibrium energy CPI by 0.53%. The long-run equilibrium between gasoline and ethanol prices is virtually identical to that estimated with the model using topline CPI (compare Equations 7b and 8b). However, gasoline prices are connected more strongly to the energy CPI than to the topline CPI, as expected (long-run elasticity of 0.53% versus 0.23%).

IRF graphs are for the P-T decomposition using the same procedures and identification assumptions as for the topline CPI model are provided in Figures 7-9. Responses to a permanent shock (Figure 7) are again normalized so the long-run permanent increase in gasoline price is 1% and the associated long-run increases in ethanol prices and CPIEN are consistent with the cointegration results. Furthermore, energy prices do not initially overshoot their long-run equilibrium values and adjust to them much more quickly than in the model with topline CPI. Together these results show that long-run equilibrium values of energy prices have a much closer relationship with long-run equilibrium values of the energy CPI compared to topline CPI (as expected). Furthermore, transitory shocks to gasoline prices (Figure 8) and ethanol prices (Figure 9) now induce short-run adjustment in the energy CPI, with transitory gasoline price shocks being more persistent than transitory ethanol price shocks. Hence there is both a short-run connection and a more significant long run connection between energy prices and the energy CPI compared to energy prices and topline CPI.

6. Results for Energy Prices and the PPI

The final trivariate model estimation results we report are for gasoline prices, ethanol prices, and the topline PPI. Lag length selection criteria again support two lagged differences in the VEC (i.e., q = 2) and there is no evidence of residual autocorrelation from this model. Results from estimating the two cointegrating vectors are:

(9a) $$\underset{}{ln(PPI_t) = 4.966 + \underset{(15.11)}{0.329}\, ln(PGAS_t)}$$

(9b) $$ln(PETH_t) = 0.437 + \underset{(13.78)}{0.453}\, ln(PGAS_t)$$

where again numbers in parentheses are consistent t-statistics. The two cointegrating vectors are almost identical to those estimated with topline CPI, the only difference being that the long run elasticity between gasoline prices and the PPI is slightly higher than for the topline CPI (0.33% versus 0.23%). This suggests that IRF analysis under the P-T decomposition will be very similar to that for topline CPI, which indeed turns out to be the case. IRF graphs for this model (not shown) show that permanent shocks overshoot long-run gasoline and ethanol prices but that the PPI adjusts to its new long-run equilibrium level almost immediately. Similarly, transitory shocks to gasoline and ethanol prices have virtually no effect on the PPI. Therefore, similar to the relationship between energy prices and topline CPI, only permanent increases in energy prices are associated with increases in the PPI, with the proportional increase in the latter being considerably smaller than proportional increases in the former (about one third). Transitory energy prices have virtually no effect on the PPI, even in the short run. Evidently, other producer prices only respond to increases in energy prices that are perceived as being permanent, with little effect when price increases are perceived as transitory.

7. Deviations from Long-Run Equilibrium Relationships

We also analyze the time path of equilibrium errors from the VEC model and identify periods where variables are in long-run equilibrium versus periods of divergence. We do this in-sample as well as make out of sample forecasts. The goal is to identify periods where long-run equilibrium relationships fail to hold and analyze how these periods get resolved. To conserve space we do this for the CPI model only but PPI results are similar.

To analyze deviations from the long-run gasoline price-CPI relationship we use the cointegration equation (7a) to forecast long-run equilibrium gasoline prices conditional on observed CPI both in-sample and over the August 2014-February 2015 out-of-sample period.[5] The resulting estimates of long-run equilibrium gasoline prices are then graphed against actual gasoline prices over the same period (see Figure 10). The difference between the two lines in the graph represents deviations from long-run gasoline price-CPI equilibrium. The graph shows that gasoline prices can stay out long-run equilibrium with the CPI for extended periods of time (years at a

[5] CPI data for February 2015 is not yet available so we used the January value to construct the conditional forecasts for February (i.e., we assumed no change in the CPI between January and February 2015).

time). Therefore, deviations from this equilibrium relationship can be quite persistent. In particular, gasoline prices were considerably higher than their long-run equilibrium value during the commodity price boom run up to the financial crisis of 2008 and considerably lower in the aftermath of the crisis. We also see that the recent decline in gasoline price at the end of 2014 and beginning of 2015 has left prices considerably below their long-run equilibrium levels with the CPI. Indeed, the only period when gasoline prices have been as low relative to their equilibrium relationship with the CPI as they are today was during the financial crisis of 2008. This suggests we can expect one (or both) of two things to happen to bring gasoline prices back into long-run equilibrium with the CPI—either gasoline prices have to rise or significant deflation has to occur. Previous episodes of relatively low gasoline prices would suggest gasoline prices will experience much of the (upward) adjustment. However, the adjustment can be slow so it is not obvious when realignment will take place.

To analyze deviations from the long-run ethanol-gasoline price relationship we use the cointegration equation (7b) to forecast long-run equilibrium ethanol prices conditional on observed gasoline prices both in-sample and over the August 2014-February 2015 out-of-sample period.[6] The resulting estimates of long-run equilibrium ethanol prices are graphed against actual ethanol prices over the same period (see Figure 11). The graph shows that ethanol prices stay close to their long-run equilibrium with gasoline price much of the time, with deviations being resolved much more rapidly than was the case for the gasoline price-CPI relationship. Therefore, deviations from this equilibrium relationship are less persistent. Ethanol prices were considerably higher than would be indicated by their long-run equilibrium with gasoline prices during the 2006-2007 commodity price boom, a period when gasoline prices have already been shown to be high relative

[6] Ethanol price data for February of 2015 is not yet available so we used the January 2015 value to construct the conditional forecasts for that month (i.e., we assumed no change in ethanol prices from January to February 2015).

to their long-run equilibrium with the CPI. We also see that ethanol prices have maintained their long-run equilibrium relationship with gasoline prices during the recent decline in the price of gasoline at the end of 2014 and beginning of 2015 (i.e., ethanol prices have fallen along with gasoline prices). Therefore, as gasoline prices re-establish their long-run equilibrium relationship with the CPI by rising over time we can expect ethanol prices to also rise accordingly.

8. Conclusion

This paper uses the Gonzalo and Ng (2001) P-T decomposition to analyze the dynamic effects of permanent and transitory energy price shocks on alternative measures of the general price level. We find that only permanent shocks influence topline CPI and PPI with transitory shocks having virtually no effect. We explain this phenomenon in terms of the response of other consumer and producer prices to energy price shocks. If the change is viewed as permanent other prices respond and the CPI and PPI adjust, though by only a fraction of the proportional increase in gasoline and ethanol prices. If the change is viewed as temporary then other prices do not adjust and the effect on topline CPI and PPI is minimal, even in the short run.

These conclusions are moderated somewhat if we do the analysis on energy components of the indexes. As we might expect, the proportional response of the energy CPI (and PPI) to a permanent shock is closer to the associated proportional increase in gasoline and ethanol prices. There is also more of a short run response in the energy CPI (and PPI) to transitory shocks compared to the topline CPI and PPI. Therefore, energy price changes are more connected to increases in the energy components of indexes than to the topline indexes, in both the short run and the long run (as expected).

We also examine the nature of deviations from estimated long-run equilibrium relationships. Results suggest that, despite the recent decline in gasoline prices, gasoline and ethanol prices have remained close to their long-run equilibrium relationship as ethanol prices have fallen along with gasoline prices. However, both gasoline and ethanol prices are currently quite low relative to their long-run equilibrium relationship with the CPI, suggesting that considerable adjustment will need to take place moving forward.

References

Brown, S. P.A. and M.K. Yücel (2002). Energy prices and aggregate economic activity: an interpretative survey. *The Quarterly Review of Economics and Finance* 42: 193–208.

Ciaian, P., and d'A. Kancs (2011). Interdependencies in the energy-bioenergy-food price systems: A cointegration analysis. *Resource and Energy Economics* 33(1): 326-348.

Cologni, A. and M. Manera (2008). Oil prices, inflation and interest rates in a structural cointegrated VAR model for the G-7 countries. *Energy Economics* 30: 856–888.

Cunadoa, J. and F. Perez de Gracia (2005). Oil prices, economic activity and inflation: evidence for some Asian countries. *The Quarterly Review of Economics and Finance* 45: 65–83.

Ewing, B.T. and M.A. Thompson (2007). Dynamic cyclical comovements of oil prices with industrial Production, consumer prices, unemployment, and stock prices. *Energy Policy* 35: 5535–5540.

Gonzalo, J. and C. Granger (1995). Estimation of common long-memory components of cointegrated systems. *Journal of Business and Economic Statistics* 13(1): 27-35.

Gonzalo, J. and S. Ng (2001). A systematic framework for analyzing the dynamic effects of permanent and transitory shocks. *Journal of Economic Dynamic and Control* 25: 1527-1546..

Hamilton, J. D. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy* 91: 28–248.

Hamilton, J. D. (1994). *Time Series Analysis*. Princeton University Press, Princeton NJ.

Hecq, A., F.C. Palm, and J-P Urbain (2000). Permanent-transitory decomposition in VAR Models with cointegration and common cycles. *Oxford Bulletin of Economics and Statistics* 62(4): 511-532.

Hooker, M. (2002). Are oil shocks inflationary? Asymmetric and nonLinear specification versus changes in the regime. *Journal of Money, Credit, and Banking* 34: 540-561.

Lardic, S. and V. Mignon (2008). Oil prices and economic activity: An asymmetric cointegration approach. *Energy Economics* 30: 847–855

Proietti, T. (1997). Short-run dynamics in cointegrated systems. *Oxford Bulletin of Economics and Statistics* 59(3): 405-422.

Stock, J.H., and M.W. Watson (1988). Testing for common trends. *Journal of the American Statistical Association* 83(404): 1097-1107.

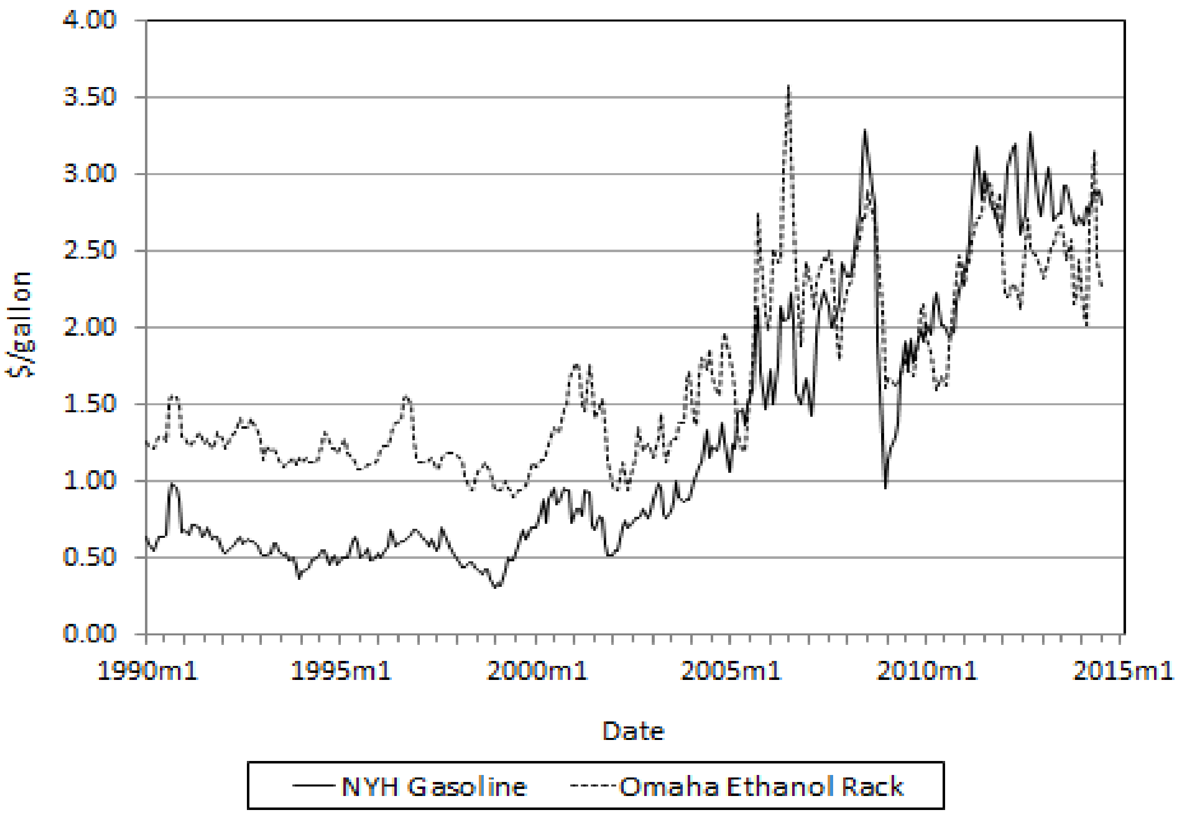

Figure 1. Gasoline and Ethanol Prices, January 1990 to June 2014

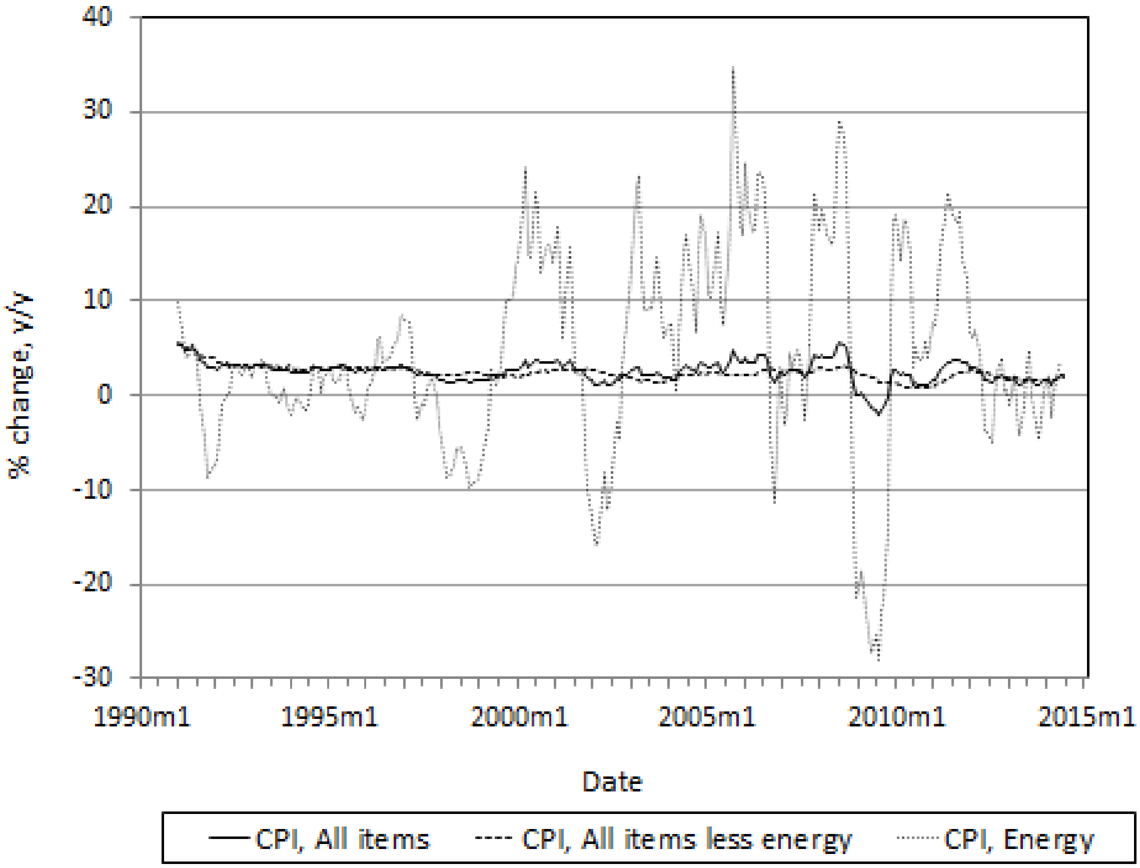

Figure 2. Year over Year Changes in monthly CPI components, January 1990-June 2014

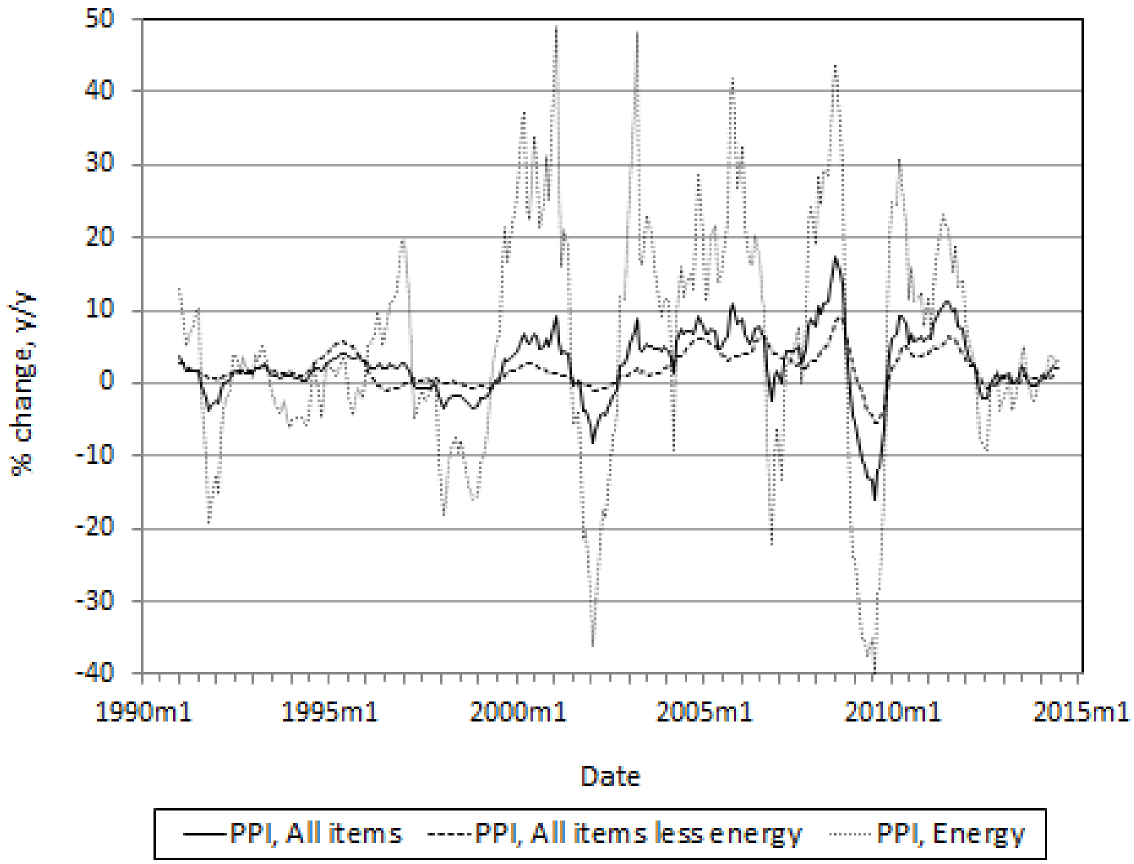

Figure 3. Year over Year Changes in monthly PPI components, January 1990-June 2014

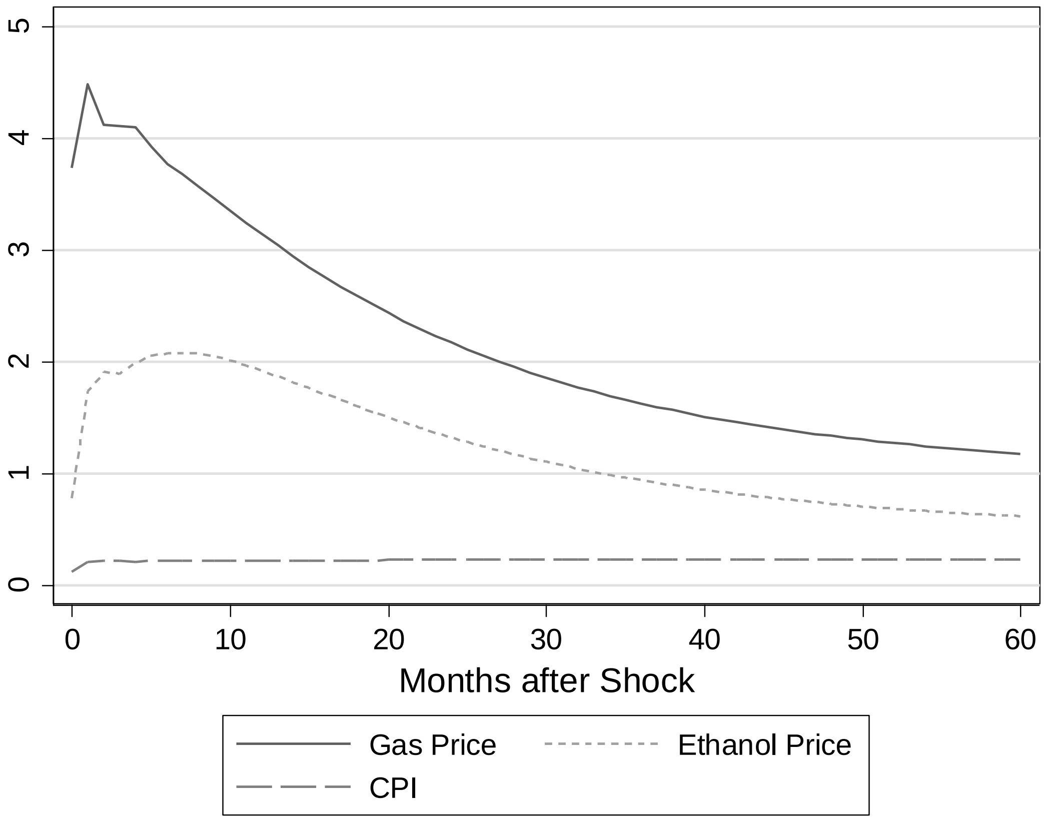

Figure 4. Impulse Response to a Permanent Shock

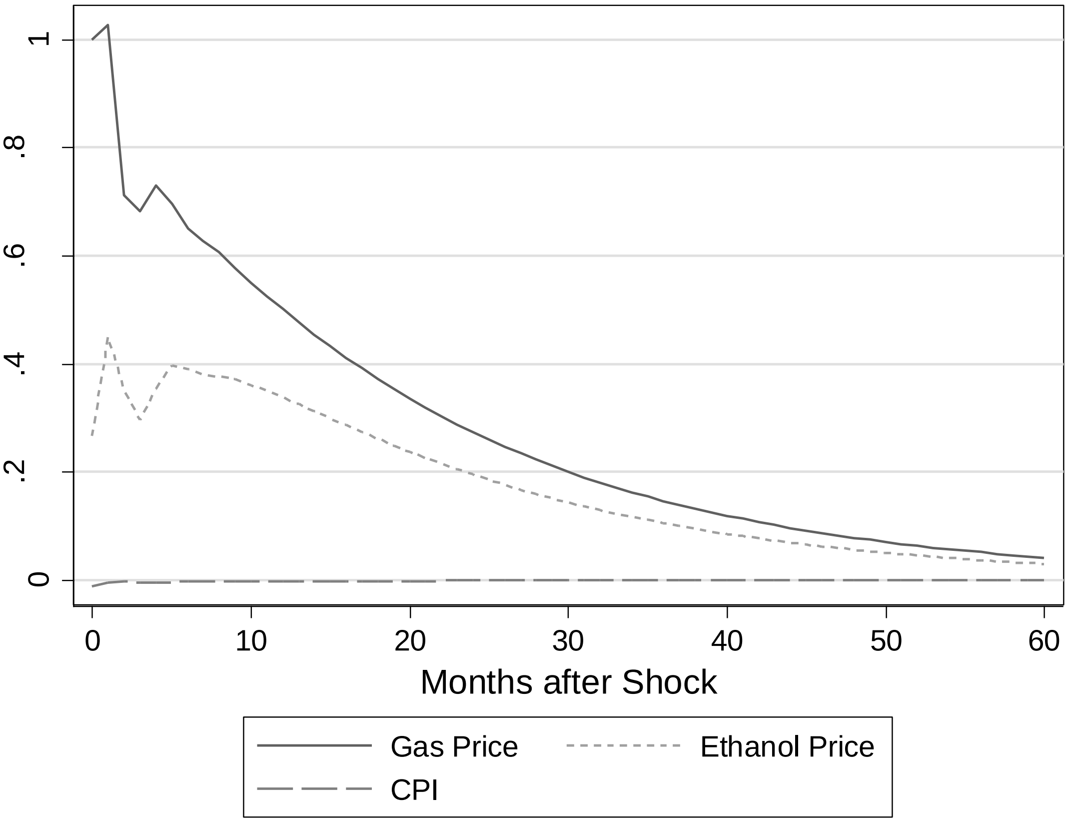

Figure 5. Impulse Response to a Transitory Gasoline Price Shock

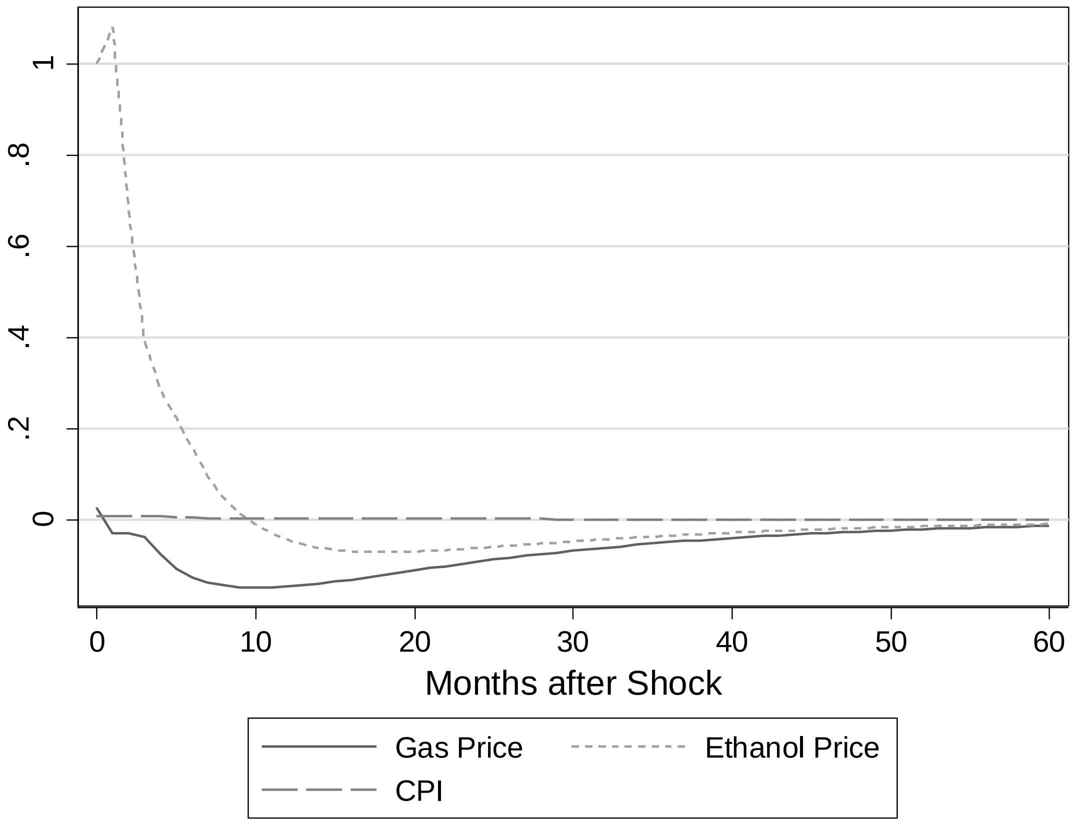

Figure 6. Impulse Response to a Transitory Ethanol Price Shock

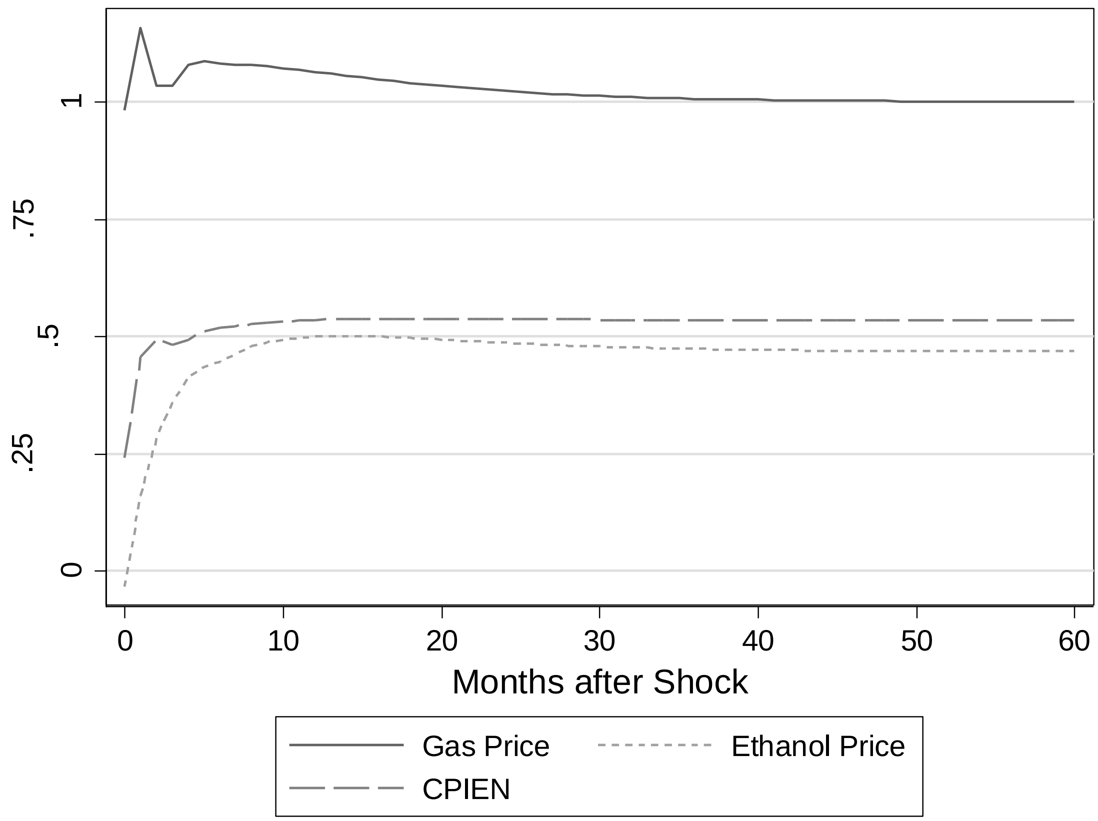

Figure 7. Impulse Response to a Permanent Shock

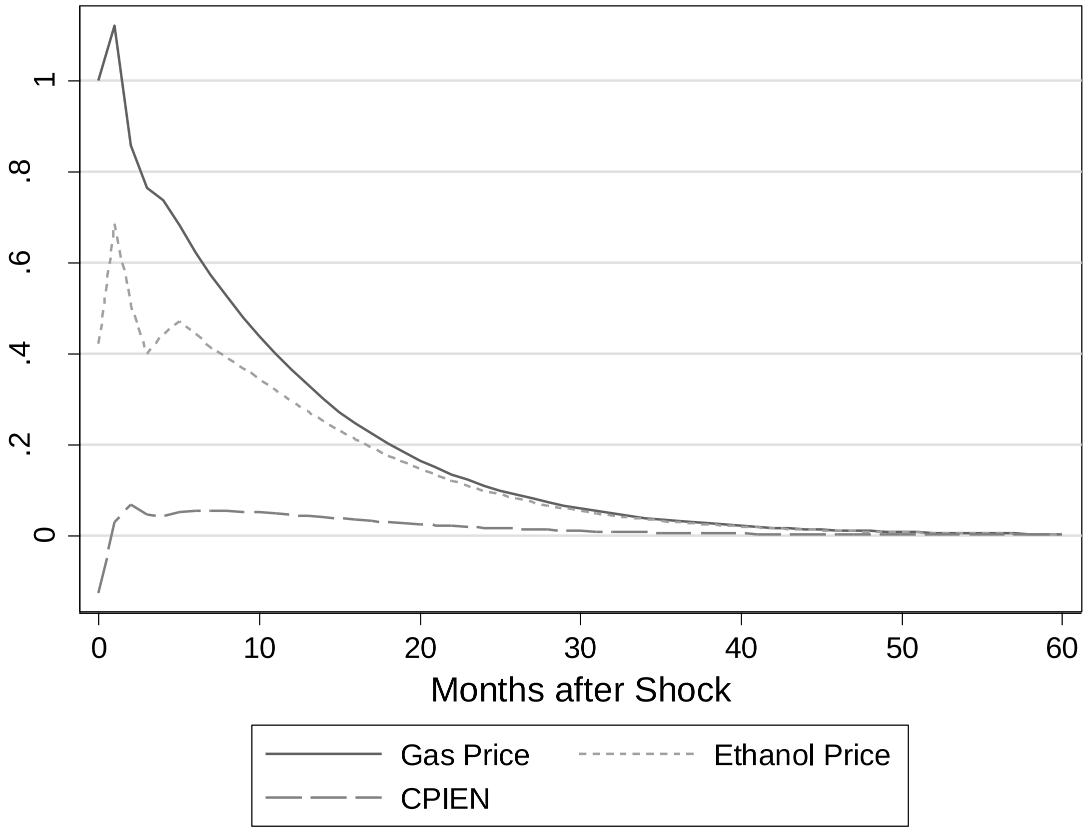

Figure 8. Impulse Responses to a Transitory Gasoline Shock

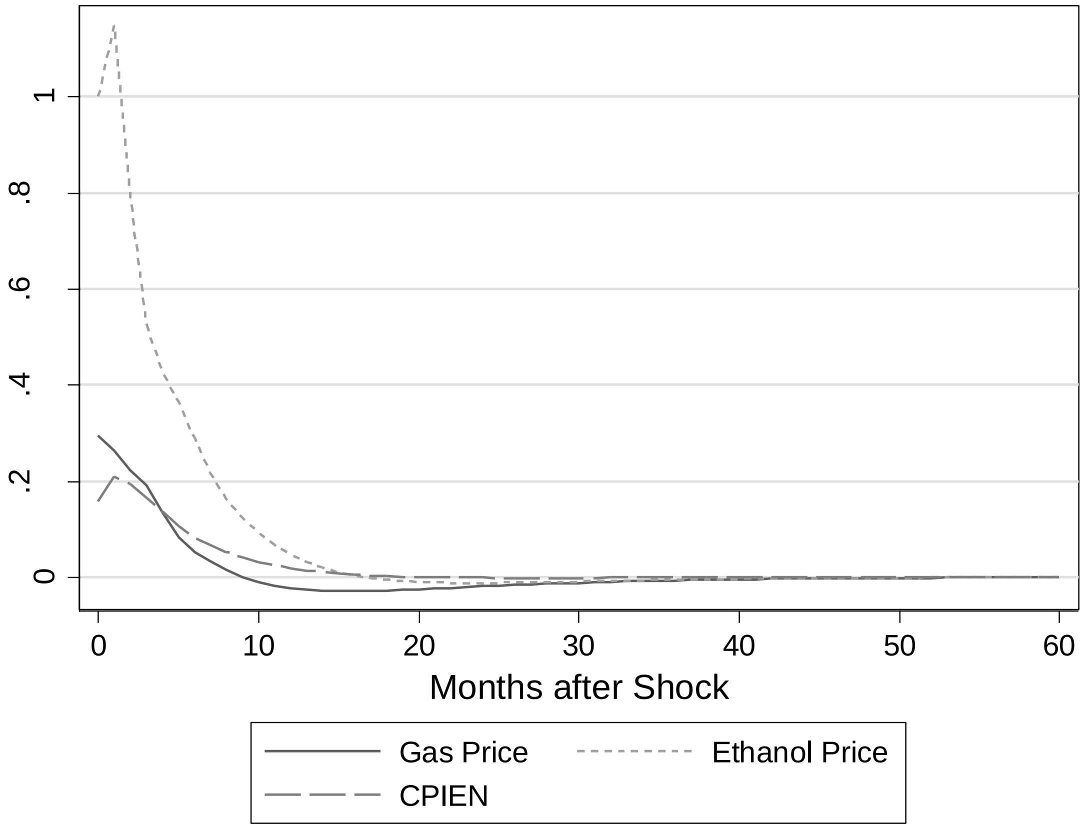

Figure 9. Impulse Responses to a Transitory Ethanol Shock

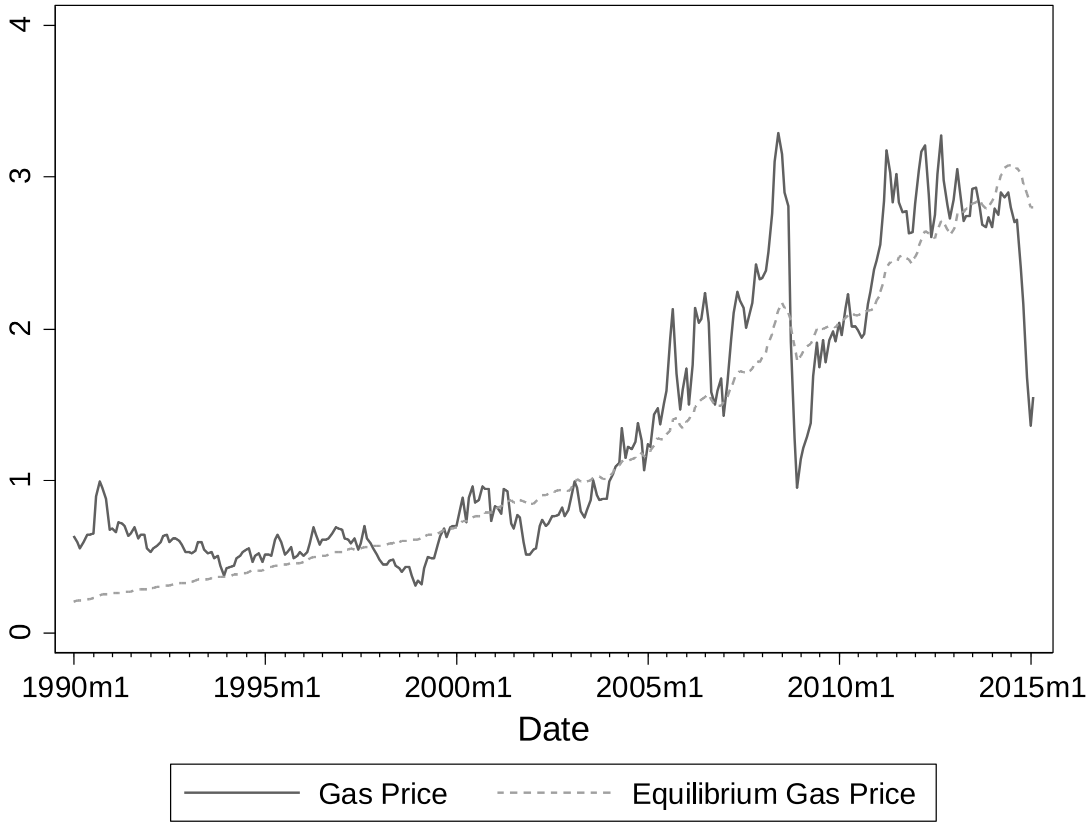

Figure 10. Deviations from Long-Run Equilibrium Gasoline Price-CPI Relationship

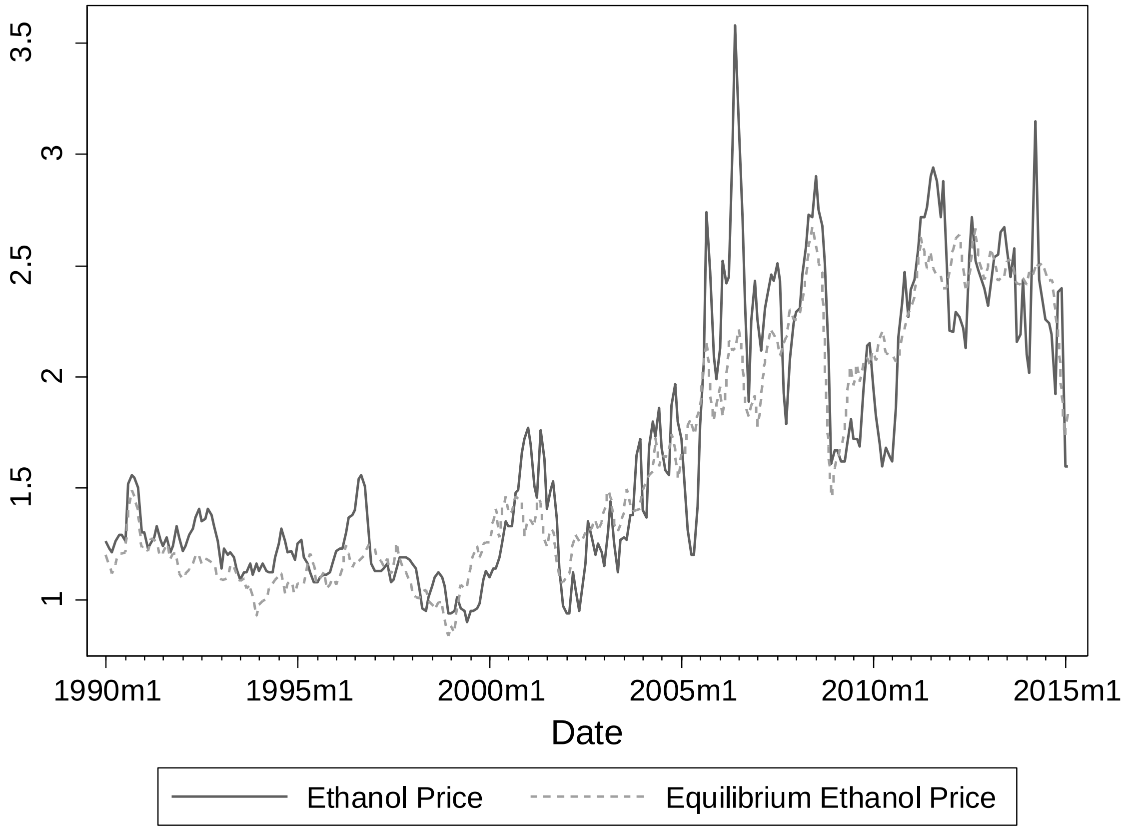

Figure 11. Deviations from Long-Run Equilibrium Gasoline-Ethanol Price Relationship

Table 1. Unit Root Test Results

Variable	*Test*	*Statistic*	*p-value*
Gasoline Price	Dickey-Fuller	-0.996	-2.878
	Phillips-Perron	-0.941	-2.878
	GLS Dickey-Fuller	-2.062	-2.900
Ethanol Price	Dickey-Fuller	-2.004	-2.878
	Phillips-Perron	-2.065	-2.878
	GLS Dickey-Fuller	-2.829	-2.900
CPI	Dickey-Fuller	-1.614	-2.878
	Phillips-Perron	-1.656	-2.878
	GLS Dickey-Fuller	-1.600	-2.900
Energy CPI	Dickey-Fuller	-0.730	-2.878
	Phillips-Perron	-0.620	-2.878
	GLS Dickey-Fuller	-2.501	-2.900
PPI	Dickey-Fuller	-0.157	-2.878
	Phillips-Perron	0.086	-2.878
	GLS Dickey-Fuller	-1.866	-2.900

Notes: All variables are in logarithms. Dickey-Fuller tests are augmented with 3 lagged differences included in the estimation equations (suggested by lag length selection tests) and the number of Newey-West lags in the Phillips-Perron tests is the suggested default of $\text{int}\{4(N/100)^{2/9}\}$ where N is the number of observations. The number of lags for the Dickey-Fuller GLS test (with trend) is chosen by the Schwarz criterion.

Table 2. Cointegration Test Results

Cointegrating Relationship	*Maximum No. of Cointegrating Relationships*	*Trace Statistic*	*5% Critical Value*
CPI and Energy Prices	0	64.115	29.68
	1	25.955	15.41
	2*	2.192	3.76
Energy CPI and Energy Prices	0	61.773	29.68
	1	17.429	15.41
	2*	0.598	3.76
PPI and Energy Prices	0	49.952	29.68
	1	15.815	15.41
	2*	0.002	3.76

Notes: All variables are in logarithms. Trace statistics based on VEC estimation with two lagged differences included in each model (as suggested by lag selection criteria). * indicates the number of cointegrating vectors supported by the statistics.