Are Prices Procyclical? : A Disaggregate Level Analysis [*]

Hemant Patil
Department of Economics
East Carolina University
M. S. Research Paper

Abstract

This paper is an empirical investigation of the comovement of prices and output in the postwar period at the disaggregate level. The correlation between these two macro variables is measured using VAR forecast errors. This measure does not require any *a priori* assumptions about the order of integration. The results reject the notion of procyclical prices in the long run. These results are in conformity with the findings of Den Haan (2000) at the aggregate level. The most plausible explanation for such behavior appears to be the presence of supply shocks in the long run.

[*] The author would like to thank Dr. Randall Parker for his insightful comments and fruitful discussions at every stage of completion of this paper.

I. Introduction

The relationship between real and nominal variables has been an important source of debate in modern macro theory. Most of the modern macroeconomic theories that attempt to explain business cycle behavior can be viewed in the context of various versions of the Phillips curve. The procyclical behavior of prices, if somewhat paradoxical, was taken be a stylized fact that many macro models needed to explain. Cooley and Ohanian (1991) in a noted study presented evidence contrary to this widely accepted maxim. No definite and consistent pattern was observed in the correlation between prices and output. This finding was difficult to explain using the existing business cycle models. This is still an unresolved issue in the literature and there is no consensus regarding any specific measure to capture the correlation.

Cooley and Ohanian (1991) prompted many macro theorists to revise their models that accommodate the positive relationship between prices and output observed in post-war data. These models primarily employed the unconditional correlation to summarize the relationship. As will be discussed in the literature review of this paper, the unconditional measure might be biased as it tends to ignore the dynamic aspects of the underlying series. Den Haan (2000) suggests using conditional correlation coefficients to measure the comovement which can correct for this bias. The use of this measure also helps in identifying the appropriate model.

This paper attempts to study the comovement between output and prices using disaggregate level data. The relationship has been studied rigorously at the aggregate level. However there has not been much work done using disaggregate level data. Burns and Mitchell (1947) in their pioneering study used disaggregate data in the analysis of short-run movements in economic activity. Romer (1987, p. 2) strongly suggests disaggregate level analysis to examine economic fluctuations. According to her, the disaggregate level analysis "allows …both to examine common behavior of all series and to pinpoint important differences in the behavior of series representing different sectors of the economy." Kuznets (1930) explored the relationship between prices and output for 19th and early 20th centuries, but the motivation for his study had more to do with a lack of data at the aggregate level. Recently Gauger (1988) used disaggregate level data to test the monetary neutrality hypothesis.

While the data used in this paper are for individual production and price series, the techniques used to identify the relationship are similar to those used by Den Haan (2000). Thus, the disaggregate level investigation, along with the estimation procedure which takes into account the underlying dynamism of the series should provide valuable empirical information to study the price-output relationship.

This paper proceeds as follows: Section II reviews the existing literature on the cyclical behavior of prices. Section III discusses the data and explains the time series methods used in this research. Section IV presents the results and their interpretation. Finally section V concludes.

II. Literature Review

Business cycle theories are judged on their ability to explain and mimic the correlations observed among macroeconomic variables. Positive comovement between output and prices was considered to be one of the best established and uncontroversial features of empirical business cycle behavior until recently. It was emphasized as a central feature in both neo-classical and neo-Keynesian macroeconomic models. While earlier analyses explained it as an extension of the Phillips curve argument, neo-classical economists such as Lucas (1972, 1977) attempted to explain it in terms of the positive relationship between unexpected inflation and real output. Some more recent studies, for example, Mankiw (1989, p.88) argued that in the absence of ‘identifiable real shocks’ inflation is positively correlated with output.

Cooley and Ohanian (1991) attempted to reexamine the correlation between output and prices. It was purely an empirical exercise and they studied the data from 1822 to 1991. For analytical purposes the price and output series were decomposed in four distinct periods, namely, pre-civil war, pre-WWI, inter-war and the post-WWII period. They present a graphical representation of prices and output for both non-detrended and detrended (using first differences) series. The results of the graphical analysis can be summarized as follows: For the pre-civil war period non-detrended contractions and expansions there was no consistent relationship between prices and output. In fact, some of the contractions seemed to exhibit a negative relationship. For the same period the detrended series supported a positive relationship in some expansions and a negative relationship in some expansions. For the pre-WWI period in the non-detrended data the relationship was ‘ambiguous’ but there were some sub-periods where a negative relationship was evident but the detrended series did not exhibit any distinct pattern. For the inter-war period a positive relationship was visible unambiguously in the non-detrended as well as detrended data. For the post-WWII period the relationship was clearly positive for the non-detrended series but the detrended series exhibited mixed patterns.

The paper then proceeds to a more formal analysis of the relationship between prices and output. Simple correlations showed that the correlations in the post-WWII period are negative. The results for 19th century data were mixed and this mixture was robust to various trend specifications. The relationship turned out to be positive for the inter-war period. The paper further examines the claim that the change in inflation (that is, the second derivative of price level) is positively correlated with output. But the authors found no empirical evidence to support this claim. They estimated vector auto regressions (VARs) using prices, output, money stock and interest rates. The conclusion of the VAR analysis is that although output Granger-causes prices, there is no strong relationship between the two variables. In summary Cooley and Ohanian (1991) demonstrated that business cycle models do not have to rely on a procyclical feature of prices since this feature is empirically questionable.

After the publication of Cooley and Ohanian's (1991) pathbreaking study which suggested that procyclical behavior of prices as a central feature of business cycle models was 'unnecessary', some economists attempted to revise macroeconomic models to incorporate these new findings. Rotemberg (1996) reproduced his original sticky price model and concluded that his model is consistent with the conclusions of Cooley and Ohanian (1991) and that it generates a negative correlation between expected output and prices. As he (1996, p. 506) noted:

> A simple sticky price model subject only to monetary shocks predicts a negative correlation between predictable prices and output movements over long horizons.

He hypothesized that a positive monetary shock raises both prices and output in the short run. But assuming that in the long-run monetary impulses have no effect on output, output is expected to decline back to its original level. On the other hand prices are expected to continue rising until the increase in the money supply is completely exhausted. Thus, monetary shocks have opposite effect on expectations regarding prices and output. The model is based on the assumption that reactions of money to expected and unexpected changes in productivity (i.e. supply shocks) are opposite. The model then draws conclusions about the relationship between expected and unexpected movements in prices and output. The model attributes the volatility in output mainly to monetary disturbances. Rotemberg (1996) doesn't rule out the possibility of real shocks having an impact on output completely, but suggests that in order for real shocks to have any effect on output an unusual set of responses are required from monetary policy to expected and unexpected growth in output for all time horizons.

Rotemberg's (1996) analysis presented a case for non-neutrality of money while explaining the comovement between output and prices. The neutrality proposition has been tested extensively at aggregate level in the literature. Gauger (1988) uses disaggregated data to test money neutrality. She argues (1988, p. 676) that the aggregate level support for neutrality might be the result of "resource reallocation and offsetting disaggregate level impacts". As has been argued before by Mankiw and Blinder (1984) the aggregate level impact of monetary shocks can present a misleading picture of disaggregate level real impacts. Gauger's (1988) disaggregate level analysis provides the motivation for the present paper to the extent that I try to evaluate the disaggregate level comovement between output and prices in post-WWII US data.

As has been mentioned before in this section, Rotemberg (1996) disregarded any role of supply shocks in output volatility. Rotemberg (1996) argued that the accumulated effects of monetary shocks on predicted output and prices must have an opposite sign over all forecast horizons. Den Haan (2000) proposed the correlations of VAR forecast errors to analyze the comovement between prices and output. This measure can be applied effectively for both stationary and integrated processes. He concludes that demand shocks dominate in the short run and supply shocks dominate in the long run for output and prices to have the observed negative correlation. The alternative measure introduced by Den Haan (2000) is particularly useful to distinguish between different business cycle models.

Den Haan (2000) observed that the primary reason for lack of consensus in the literature about the comovement in prices and output is the focus on only one unconditional correlation coefficient. The unconditional statistic fails to account for the dynamic nature of the variables under consideration. The unconditionalality necessitates transforming the data in order to make it stationary. There are many ways to deal with the issue and this is one of the main sources of disagreement. Den Haan (2000) then proposes the conditional correlation coefficient based on VAR forecast errors at different horizons. The VAR system can be used effectively for both stationary and integrated processes as mentioned earlier and the researcher doesn't have to make identifying assumptions.

Den Haan (2000) presents both bivariate and multivariate VAR systems and how they can be applied to the problem at hand. He shows that the covariance and correlation of the constructed time series of forecast errors can be estimated consistently for fixed time horizons even if the underlying process is not stationary. He further explores an alternative method using VAR which employs impulse response functions for measuring the comovement between output and prices. Although the alternative procedure offers comprehensive information about the comovement, it calls for identifying assumptions to be made and the results are sensitive to the assumptions. The measure suggested by Den Haan (2000) offers a clear advantage over the impulse response functions in the sense that it doesn't require any identifying assumptions but he also notes (p. 8) that it fails to "identify all the different impulse response functions." He also shows both graphically and mathematically, how the statistic proposed by Rotemberg (1996) results in a spurious relationship.

Den Haan (2000) uses both monthly and quarterly data to analyze the relationship in question but prefers the monthly data as the results turn out to be robust for the VAR specification and sampling period. He estimates the coefficients based on VARs that include only prices and output and a multivariate VAR which includes the federal funds rate, total reserves and the ratio of non-borrowed reserves to total reserves. He estimates each VAR twice, using the first difference of output, prices and total reserves and also using the levels. The forecast errors are calculated for the levels. He employs the Akaike Information Criterion to determine the number of lags and the deterministic trend component. He calculates the confidence bands using bootstrap methods.

Den Haan (2000) reports that the results are robust to different VAR specifications and different sample periods. The correlation coefficient for short-term forecast horizons are significantly positive and for long-term forecast horizons significantly negative. It should be noted that Rotemberg's (1996) results are very similar to Den Haan's results. But Den Haan claims that the negative correlation coefficients entail significant information for identifying the appropriate model to account for this relationship between prices and output. The sign of the unconditional correlation coefficient might be the result of the detrending method used to render the data stationary and dynamic responses in the model as noted by Ball and Mankiw (1994), Chadda and Prasad (1993), and Judd and Trehan (1995) which rules out the possibility of supply shocks which is intuitively obvious. But as earlier mentioned, Den Haan (2000) claims that his results don't suffer from the detrending method employed. He then goes on to show how sticky price models which rely on demand shocks alone, are incapable of explaining the empirical results obtained by Den Haan (2000) unless, as has been mentioned before, questionable assumptions are made about the demand shocks. He asserts the existence of demand shocks in the short-run but denies their role as a cumulative effect in the long run. He argues that in a stationary model the logical consequence of supply shocks mimic the observed negative relationship in the long run as short-run effects are not influenced by the underlying dynamics of the model or to use his words (p. 15) "short-run effects in a model are not affected by the internal propagation mechanism."

He then postulates a model which incorporates both demand and supply shocks. He observes that if prices are not perfectly flexible then the model postulated by him replicates the results in postwar data. The model is used for illustration purposes and doesn't get the detailed treatment as Rotemberg's (1996) model. He concludes that demand shocks seem to dominate in the short run and supply shocks dominate in the long run. The rationale for this conclusion comes from the adjusting mechanism of output in response to demand and supply shocks. Demand shocks influence output directly resulting in immediate adjustments in output and so have short-run effects but supply shocks influence output through the changes in prices which only happen progressively, resulting in long-run adjustments. The speed of adjustment therefore has a significant effect in determining the persistence of the shock.

Finally, Den Haan (2000) concludes by suggesting the need for a set of empirical behaviors upon which everyone can agree. The different measures employed by researchers to capture the comovement of prices and output often results in a sequence of theoretical models. Den Haan's (2000) proposed measure proves to be advantageous as it is straightforward and requires few assumptions. Also, it helps to distinguish between macroeconomic models.

III. Data and Methodology

As has been noted earlier, Den Haan's (2000) methodology is followed for estimating the correlation coefficients. This method uses the forecast errors at different horizons and it employs VARs to estimate the forecast errors. I use only bivariate VARs to calculate the forecast errors. In the case of aggregate level correlation estimates Den Haan (2000) found no significant difference between the results of bivariate and multivariate VARs.

A VAR system regresses the variable under consideration on lags of itself and lags of other relevant variables. In the present case, PPI (p_t) is regressed on the lags of itself and the lags of an output index (y_t). The equation can be specified as follows:

$$p_t = \alpha + \sum_{l=1}^{L} \beta_l p_{t-l} + \sum_{l=1}^{L} \delta_l y_{t-l} + \varepsilon_t \tag{1}$$

where α is a N-vector of constants, β_l and δ_l are N-vectors of regression coefficients, ε_t is an N-vector of innovations and the total number of lags included is equal to L. The VAR for the output index can be similarly specified as in the following equation:

$$y_t = \alpha + \sum_{l=1}^{L} \beta_l y_{t-l} + \sum_{l=1}^{L} \delta_l p_{t-l} + \varepsilon_t \qquad (2)$$

where all the symbols and subscripts have the same interpretation as in equation (1). The innovations as Den Haan (2000, p. 6) noted "…are assumed to be serially uncorrelated but they can be correlated with each other." The K-period ahead forecasts and K-step ahead forecast errors for price are denoted as $P_{f\,(t+K)}$ and $P_{e\,(t+K,\,t)}$ respectively. Similarly, for output the K-period ahead forecasts and K-step ahead forecast errors are denoted as $Y_{f\,(t+K)}$ and $Y_{e\,(t+K,\,t)}$ respectively. The covariance between $P_{e\,(t+K,\,t)}$ and $Y_{e\,(t+K,\,t)}$ is denoted by COV(K) and the correlation coefficient is denoted by COR(K). The forecast errors are constructed by calculating the difference between the actual values and their forecasts.

The COV(K) and COR(K) are consistent and COR(K) converges to the unconditional correlation coefficient as K goes to infinity given that the series is stationary. Even if the series is not stationary, COV(K) and COR(K) can be estimated consistently as Den Haan (2000) demonstrates. The advantage of this method is that assumptions about the underlying dynamics of the series are not necessary. In order for the measure to be consistent, the model needs to be specified correctly. In order to specify the model correctly, it is required that ε_t is not integrated. Then, it becomes essential to have a lag order large enough to mirror the order of stochastic processes in the underlying series. COV(K) and COR(K) are estimated at different lag levels to verify whether it has any effect on the magnitude and sign of the correlation coefficients. The

VARs are estimated both in levels and first differences. Also, various trend specifications are used to check robustness of results.

A potential source of bias in the results may be due to sampling variability as it uses estimated VARs to calculate the correlation coefficients. Runkle (1987) suggested bootstrapping to verify whether there is a bias resulting from small samples. To apply this procedure we estimate the VARs using the given sample and retain the estimated coefficients and residuals. Then, a series of random variables can be generated which can take the residual values with certain probability. Using random selection with replacement, a full sample can be obtained. This sample is used then to fit a new VAR system. A second set of series of random variables can be generated using the same procedure and a VAR can be fitted. To construct confidence intervals one should repeat this method a large number of times. In the present case, 2500 iterations are used and confidence intervals are obtained. The average correlations across iterations are not much different from the original correlations, so there is no small sample bias.

The model for this research focuses on the disaggregate level correlation between prices and output in post-WWII US data. The procedure described above is used to analyze the comovement at the disaggregate level. For industrial production (real output) 5 different subcomponent series of the Federal Reserve index of industrial production are used. One problem that arises is which industries are to be considered for the disaggregate level analysis? Gauger (1988) uses 10 different subcomponents series for the disaggregate level evidence. As has been mentioned in the review section, the speed of the price adjusting mechanism in different industries is an important determinant of the relationship, at least in the short run. This paper therefore uses broad subcategories of industrial production which have sufficient variability as far as the nature of price and output adjustments is concerned. The subcategories are as follows: consumer durables, non-durable consumer goods, chemical products, crude and petroleum, and electric utility sales. The producer price index (PPI) for these subcategories is used to represent the price level. Monthly data are used to construct both the series for all the subcomponents as Den Haan (2000) notes that at the aggregate level, results based on monthly data are more robust to various specifications. Also, the sample size is richer if monthly data are employed. Choosing the 'sufficiently large' lag length for VAR system is also an issue as innovations can be integrated. In this paper, results are obtained by using 1 lag, 6 lags and 12 lag models.

The sample period for consumer durables and consumer non-durables is from 1947:01 to 2003:2. The sample period for chemical products is from 1954:01 to 2003:02. The sample period for petroleum products and electric sales is from 1972:01 to 2003:02. The VARs for each subcomponent are estimated using linear and quadratic trend for levels. The VARs in first differences are estimated without specifying the trend and specifying a quadratic trend.

IV. Results

The results of the correlation are obtained using the procedure described in the previous section. In the case of consumer durable goods the results are very similar across all different VAR specifications and trend specifications. As shown in Figure 1, which is representative of all the results for durable goods for the short-term forecast horizons the correlation coefficients are significantly positive and for the long-term forecast horizons the correlation coefficients are significantly negative. There are a few correlation coefficients, particularly at lag length of 1, which are negative but they turn out to be statistically insignificant. These are highly consistent with the results of Den Haan's (2000) aggregate level results.

The results for consumer non-durables are in line with the results of consumer durables for all lags together. For short-run forecast horizons the correlation coefficients for forecast errors are positive and significant and for longer horizons they are negative and significant. It is noteworthy that the nature of production and the adjusting mechanisms in durables and non-durables are vastly different. Still the comovement between output and prices exhibits a similar pattern. For smaller lag lengths the negative correlation doesn't last for many periods. Figure 2 depicts the behavior of the comovement for one lag. It should be noted here that both subcomponents, namely durables and non-durables, have the same sample period and the results are comparable. The results discussed below have different sample periods and comparison across all the 5 subcomponents is difficult.

The correlation coefficients for chemical products exhibit a completely different pattern for short-run forecast horizons. The correlation coefficients are mostly negative but insignificant for the short-run forecast horizons but for the long run they confirm the pattern observed in case of durables and non-durables. The short-run behavior of prices and output might be affected by the atypical nature of the adjusting mechanism in the chemical industry. But this is just an intuitive possibility. At the least these results are incompatible with procyclical price behavior in the chemical industry.

The results from electric sales are negative corroborating the evidence from chemicals, durables and non-durables. But the most surprising aspect of these results is that the correlation coefficients are statistically insignificant even for long-run horizons. These results may reflect the advanced planning nature of the electric grid depending more on population growth than any other factor. Moreover, to the extent electricity is regionally fungible, this would weaken any cyclical behavior between prices and output.

The story is similar for petroleum goods. The correlation coefficients are positive at short-run forecast horizons and negative for the long-run forecast horizons but insignificant in most of the VAR specifications.

All the results discussed above are in general conformity with the results obtained by Den Haan (2000) at the aggregate level. The results for durables and non-durables are similar despite the different nature of these industries. The results for chemicals are negative and insignificant in the short-run. The electrical and petroleum correlations coefficients are not statistically significant. The pattern which clearly emerges from these results is that the disaggregate level data supports the evidence at the aggregate level as far as the comovement between output and prices is concerned. The forecast errors are positively correlated at short-run forecast horizons and negatively correlated at long-run forecast horizons. At the least these results are inconsistent with long-run procyclical price behavior.

A typical sticky price model attributes the short-run and long-run comovement between output and prices to demand shocks. A nominal positive demand shock results is expected to increase output in immediate periods but prices are expected to remain below the trend as prices adjust slowly to demand shocks. But the output is expected to be back to its original trend level and prices are expected to rise until the increase in the money stock is completely exhausted. This model fails to generate negative covariance between forecast errors as it requires that the accumulated effect of a positive demand shock on output to be negative. Den Haan (2000) suggested the presence of supply shocks in the long run and the results discussed in this section support the hypothesis. But one can argue the presence of both types of shocks in the long run. Den Haan’s (2000) argument is that in the short-run a demand shock influences output directly and so demand shocks are dominant. But in the long run supply shocks are dominant.

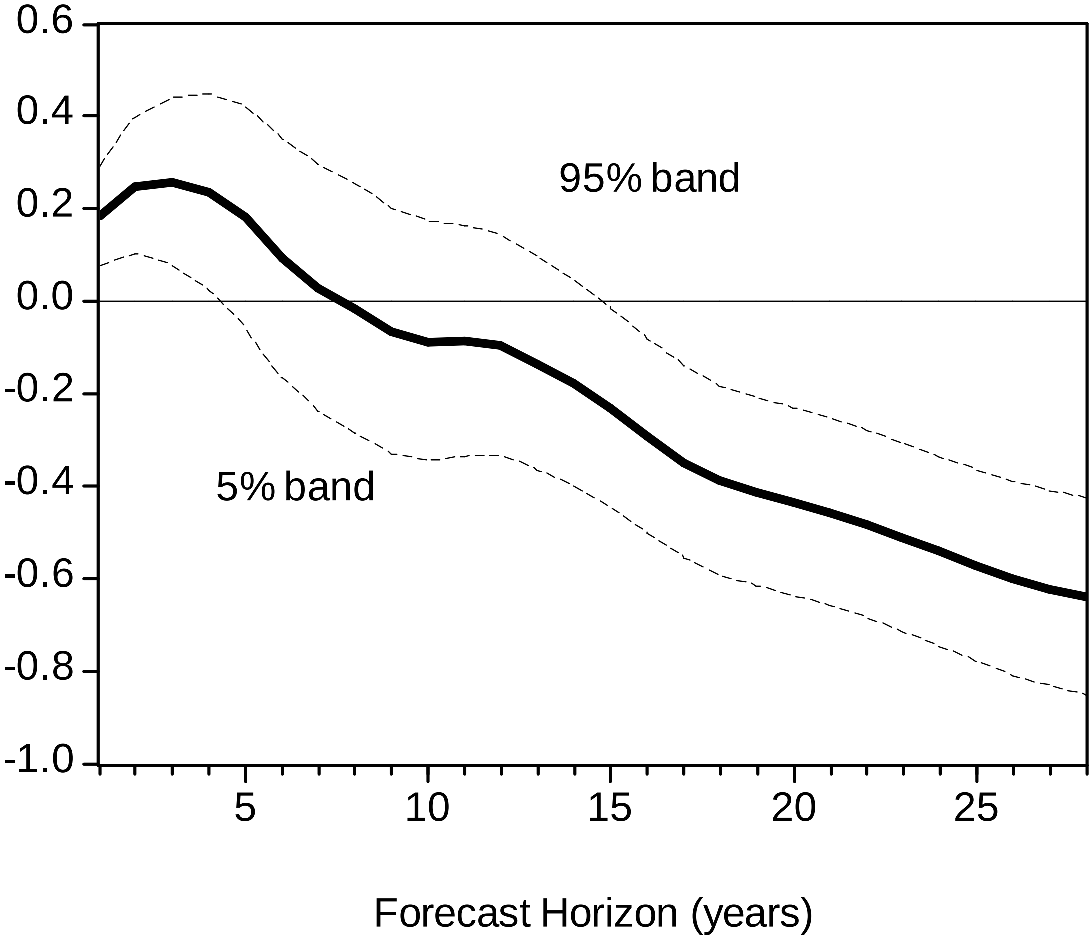
In summary, the results confirm the aggregate level evidence that in the short run the comovement is positive and in the long run prices and output move in the opposite direction. The evidence is very strong in the case of consumer durables and consumer nondurables. However in the case of chemicals the short run correlation coefficient is negative and insignificant. The results from electric sales and petroleum are negative in the long run but mostly insignificant.

V. Conclusion

Aggregate level analysis of the comovement between output and prices has been extensively conducted in the literature. There are few examples of disaggregate level analysis of this phenomenon. To draw any concrete conclusion about the relationship between these two macroeconomic variables disaggregate level results should be able to mimic results at the aggregate level. The aggregate level post-war data called in to question the earlier belief that prices and output are positively correlated. Most of these studies which verified the negative long-run relationship between output and prices, also attempted to explain it through modifying existing macroeconomic models. There is no consensus among various measures to capture the comovement.

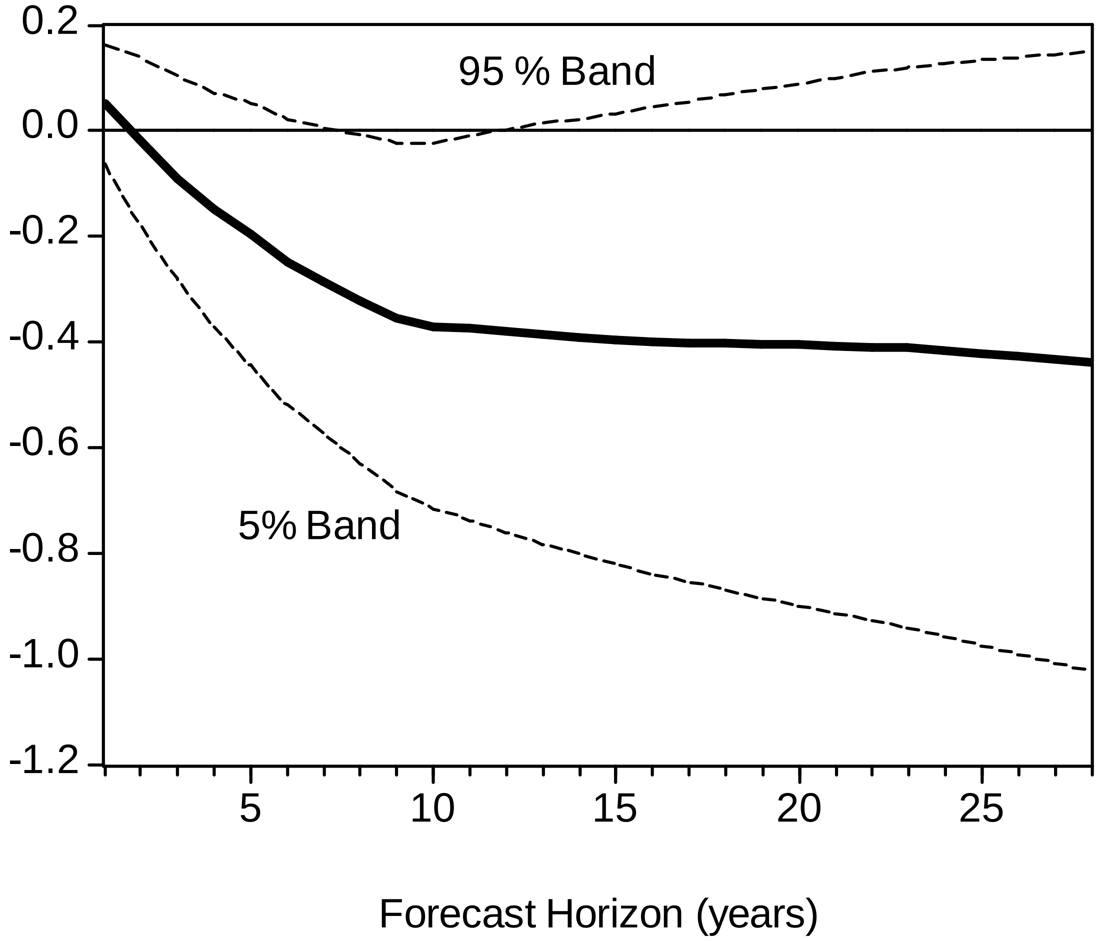
This paper uses the VAR forecast errors at different horizons to examine the relationship at the disaggregate level. This method doesn't require any ex ante knowledge about the underlying dynamics of the series. The results are very much in conformity with the results at aggregate levels. There are definitely certain aspects in the present study which can be improved upon. Only bivariate VAR systems are used and this can be extended to multivariate VAR system. More subcomponents of GDP can be employed. Nevertheless, the results of this study confirm that the evidence for the procyclical behavior of prices is very weak.

Figure 1. Durable Goods.



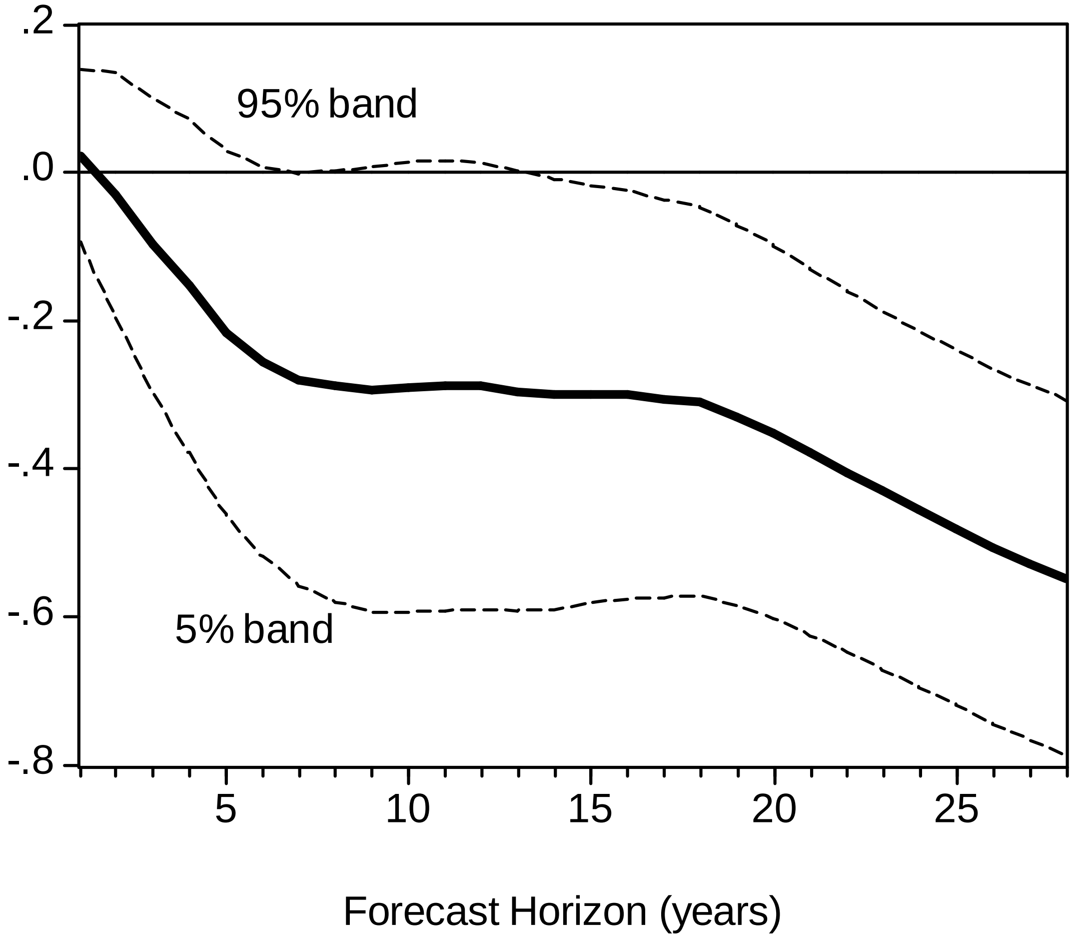
Note: This figure plots the confidence intervals (thin dotted lines) and correlation coefficients (solid bold line) that are calculated using bivariate VARs for durable goods.

Figure 2. Non-durable Goods.



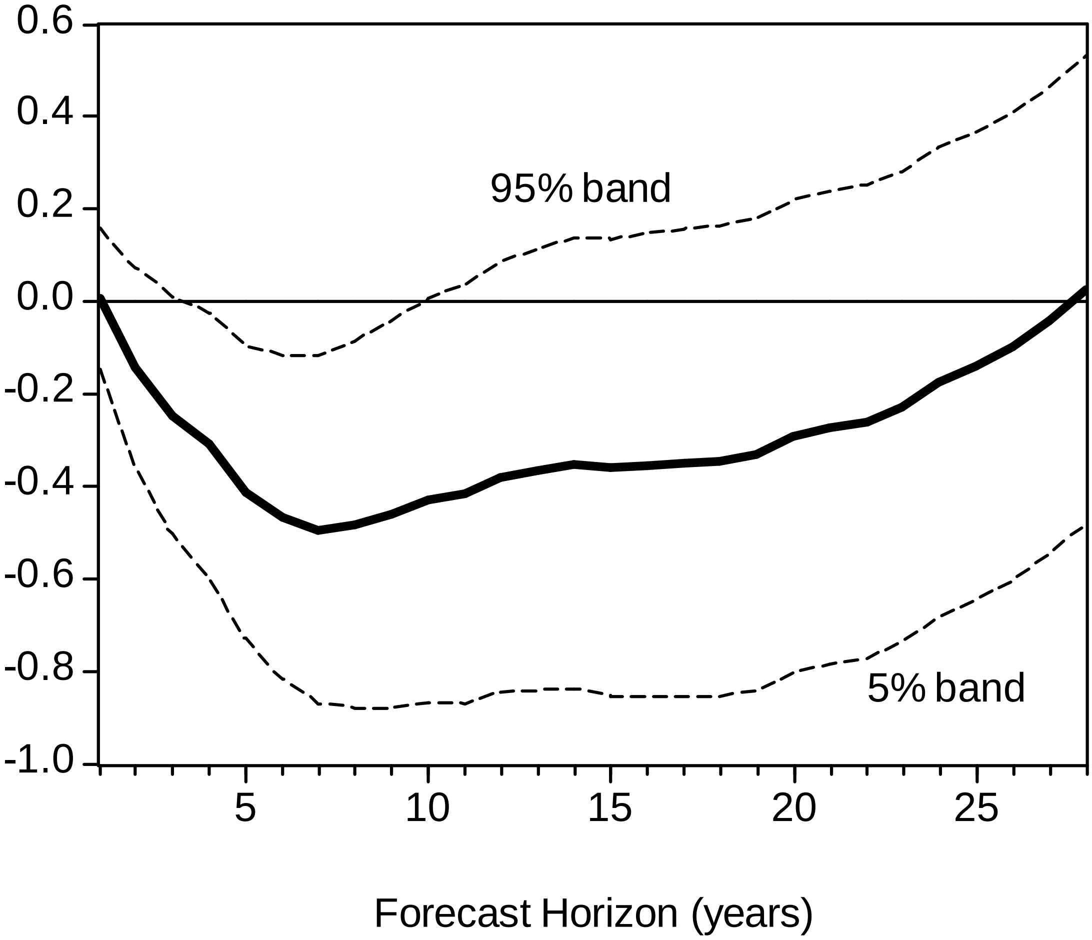
Note: This figure plots the confidence intervals (thin dotted lines) and correlation coefficients (solid bold line) that are calculated using bivariate VARs for non-durable goods.

Figure 3. Chemical Products.



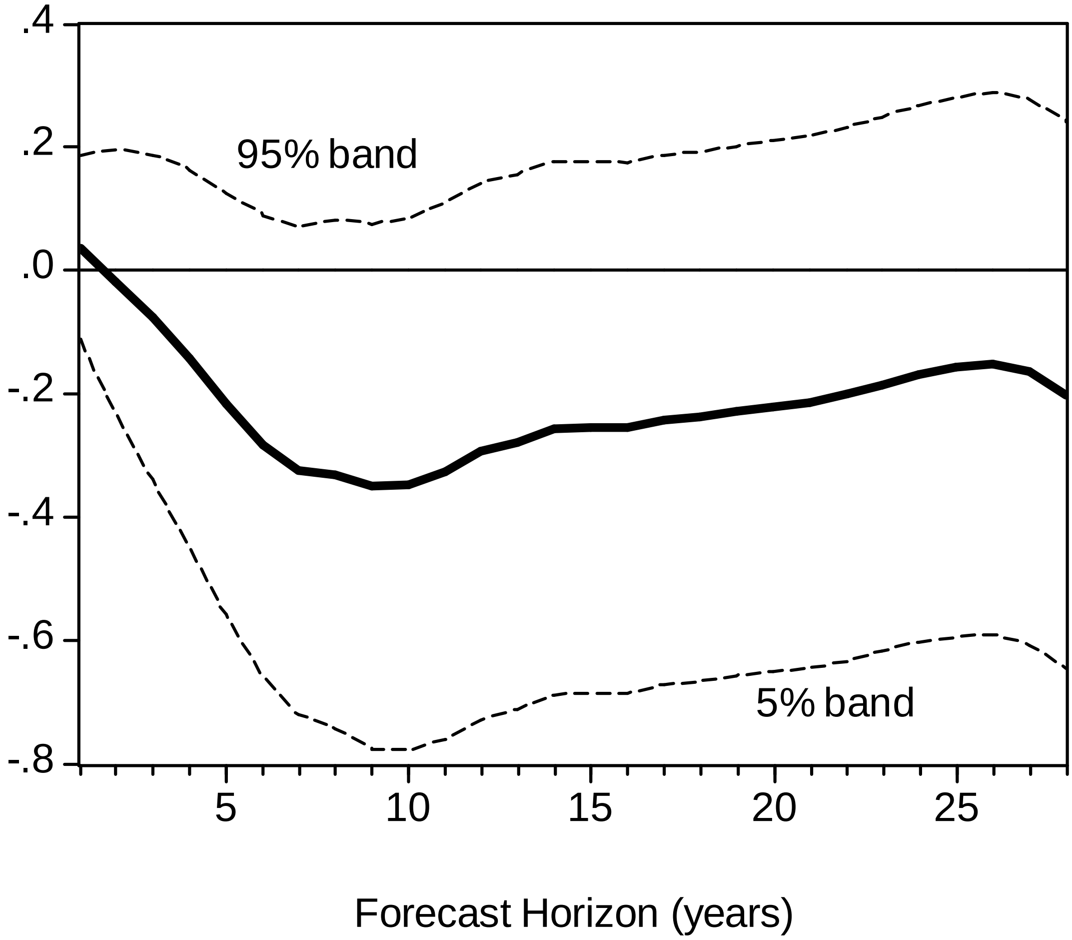
Note: This figure plots the confidence intervals (thin dotted lines) and correlation coefficients (solid bold line) that are calculated using bivariate VARs for chemical products.

Figure 4. Electric Sales



Note: This figure plots the confidence intervals (thin dotted lines) and correlation coefficients (solid bold line) that are calculated using bivariate VARs for electric sales.

Figure 5. Petroleum Products.



Note: This figure plots the confidence intervals (thin dotted lines) and correlation coefficients (solid bold line) that are calculated using bivariate VARs for petroleum products.

References

Blinder, Allen, Mankiw, Gregory N., 1984, "Aggregation and Stabilization Policy in a Multi-Conract Economy," *Journal of Monetary Economics* 13, 67-86.

Burns, Arthur F., Mitchelle Wesley C., 1947, Measuring Business Cycles, (National Bureau of Economic Research, New York, NY).

Coooley, T. F., Ohanian, L.E., 1991, "The Cyclical Behavior of Prices." *Journal of Monetary Economics* 28, 25-60.

Den Haan, W. J., 2000, "The Comovement Between Output and Prices." *Journal of Monetary Economics* 46, 3-30.

Gauger, Jean,. 1988 "Disaggregate Level Evidence on Monetary Neutrality." *The Review of Economics and Statistics*, (March 14, 1988), 676-680

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

Kuznets, Simon, 1939, Secular Movements in Production and Prices, (National Bureau of Economic Research, New York, NY).

Lucas, Robert, E., 1972, "Expectations and the Neutrality of Money." *Journal of Economic Theory* 4, 103-124.

Lucas, Robert, E., 1977, "Understanding Business Cycles." *Carnegie-Rochester Conference on Public Policy* 5, 7-29.

Mankiw, N. Gregory, 1989, "Real Business Cycles: A New Keynesian Perspective." *Economic Perspectives* 3, 79-90.

Romer, Christina D., 1987 "Changes in the Cyclical Behavior of Individual Production Series." *NBER Working Paper* No. 2440, NBER, Cambridge, MA.

Rotemberg, Julio J., 1982, "Sticky Prices in the United States." *Journal of Political Economy* 90, 1187-1211.

Rotemberg, Julio J., 1996, "Prices, Output, and Hours: An Empirical Analysis Based on a Sticky Price Model." *Journal of Monetary Economics* 37, 505-533.

Runkle, David, 1987, "Vector Autoregressions and Reality. "*Journal of Business and Economic Statistics* 5, 437-442.