Exploring the Robustness of the Oil Price-Macroeconomy Relationship

Mark A. Hooker
Federal Reserve Board, Stop 71
20th & C St., NW
Washington, DC 20551
mhooker@frb.gov

Revised, October 1997

JEL Classification Codes E32, E37

Abstract:

This paper reexamines the oil price-macroeconomy relationship with rolling Granger causality and structural stability tests. It finds that the relationship broke down amidst the falling oil prices and market collapse of the 1980s, suggesting misspecification of the oil price rather than a weakened relationship. Some proposed respecifications of the oil price yield considerable improvements, although they are not sufficient to achieve Granger causality of output unless interest rates are excluded from the VAR. There is some support for the explanation that oil prices affect the economy indirectly by inducing monetary policy responses, but this is incomplete and some evidence of misspecification remains.

This paper was originally prepared for the U.S. Department of Energy Conference on the Macroeconomic Impacts of Oil Price Shocks, Washington DC, October 3-4, 1996. Financial support from Oak Ridge National Laboratory is gratefully acknowledged. I thank Andrew Filardo and Jeff Fuhrer for helpful comments. The views expressed are those of the author, and do not necessarily represent those of the Federal Reserve System.

I. Introduction

Hamilton (1983,1985) argued that oil price changes were an exogenous and general cause of recessions in the postwar U.S. This position was controversial, as prevailing wisdom held that the OPEC supply disturbances of 1973 and 1979 were the only oil shocks with macroeconomic consequences. Thus, Hamilton's arguably most persuasive pieces of evidence were those that supported a relationship before OPEC. Chief among these were that a spike in oil prices preceded all but one of the postwar recessions, and that oil price changes strongly Granger-caused output and unemployment in data through 1972. Hamilton's efforts were largely successful: the existence of an oil price-macroeconomy relationship has become widely accepted, and oil prices now figure prominently as business press outlook factors, undergraduate textbook curve-shifters, and frontier research instrumental variables.

Ironically, during the period that this relationship was gaining adherents–and while a spike in oil prices coincided with another recession–the Granger causality evidence dramatically deteriorated. While Hamilton (1983) showed that oil prices Granger caused output at the 1% level in data through 1972 or 1980, Lee, Ni and Ratti (1995) and Hooker (1996) obtained *p*-values over .50 in comparable tests with samples ending in 1992 and '94, respectively. Repeated Granger causality tests on an expanding sample, plotted in Figure 1, show that the breakdown occurs quite suddenly as data from the 1980s is included: *p*-values are always below .10 if the sample ends before 1981, but increase sharply to .30 or more for the levels specifications after that, and for the differences specifications after 1986.[1]

Some long-term trends in the U.S. economy, like increased energy efficiency and the evolution from goods towards services production, might cause a gradual lessening of the macroeconomic consequences of oil price shocks. However, it seems improbable that oil prices ceased being an important determinant of macroeconomic activity so suddenly. Rather, most authors investigating this evidence have concluded that Hamilton's original equation misspecified

---

[1] Tests are of the hypothesis that all oil price coefficients are zero in 8 lag quarterly VARs which include GDP deflator inflation, the 3-month Treasury bill rate, and import inflation in addition to unemployment or output growth and an oil price. The two oil prices used are nominal log-differences and real log-levels (see the data appendix for exact definitions). The samples (before observations are lost to lags) begin in 1948:1 and run through 1995:2.

the functional form of the oil price, and that the falling prices of the 1980s and oil market collapse in 1986 highlighted the problem. Earlier data did not have much power to reveal misspecification, because (nominal) prices often remained constant for many periods and rarely fell before 1981.

A number of hypotheses about the channels through which oil prices affect the macroeconomy have been proposed, with different theories calling for different specifications of the oil price.[2] For example, if the primary mechanism is that oil price changes affect inflation and thus real money balances, then their real level is the right specification, while if it is through sectoral reallocations of resources, then an asymmetric specification is called for (price decreases also induce contractionary reallocations). An oil price transformation that explains the evidence in Figure 1 would have to treat the post-1986 features of oil price movements—large price declines and high volatility—very differently than do the conventional log-level or difference specifications, and this is indeed what researchers have proposed. Transformations that ignore price decreases (Mork 1989), assign volatility an important role (Ferderer 1996), or do both (Lee, Ni and Ratti 1995, Hamilton 1996) have been alleged to resolve the breakdown and support sectoral shift and/or investment-uncertainty theories of the oil price-macroeconomy transmission mechanism.

If these transformations correctly capture the relationship, they ought to Granger cause measures of economic activity across a range of sample periods and render the VARs structurally stable across episodes where the character of oil prices changed. While authors proposing these re-specifications have included some such evidence, this paper shows that they fall short of resolving either structural instability of the equations or the breakdown in Granger causality with post-1986 data.

The paper then turns to a second and complementary factor in the story. It has been recognized at least since Sims (1980) that the inclusion of short-term interest rates significantly affects 'money Granger-causes income' Granger causality tests. It is also the case that monetary policy has responded to large oil price movements, at least since the second OPEC shock in 1979. Furthermore, several authors, including Carruth, Hooker and Oswald (1997), Daniel (1997), and Hamilton (1996b) have found considerably more robust associations between oil

---

[2] See Mork (1994) for a good discussion of various mechanisms.

prices and economic activity in systems that do not include money market interest rates.

In light of these facts, the paper reanalyzes the Granger causality and structural stability evidence with short-term interest rates left out of the VARs. In these systems, all of the oil price respecifications show significantly improved performance, and Hamilton's 'net oil price increase' series emerges as a stable and robust predictor of output and unemployment. The explanation that oil prices now affect the economy indirectly, by inducing monetary policy responses, finds some support but appears to be incomplete. I conclude that incorporating aspects of asymmetry and volatility in the specification *and* accounting for the correlation with money market variables is necessary to understanding what happened to the oil price-macroeconomy relationship. Further refinement of the specifications is also called for.

The remainder of the paper is organized as follows. In section II, four proposed oil price respecifications are discussed along with theory and evidence supporting them. Section III conducts structural stability and Granger causality tests in VARs that include the Fed Funds rate, and section IV repeats these tests without interest rates in the VARs. Investigations and interpretations of the evidence are provided in section V, and section VI concludes.

II. Oil Price Re-specifications

A. Data Issues

The major change in the VARs relative to the existing literature involves the GDP accounts. Most analysis has used quarterly GDP data and samples that begin in the late 1940s; the VARs that I work with include real GDP, the GDP deflator, and the ratio of nominal to real imports. Recently, the BEA converted to chain-weighted versions of these series which begin in 1959. Since the questions I am addressing center on post-1986 data, I use the new series rather than the old ones which end in 1995 (Figure 1 uses the old series for comparison with the literature). After lags are used in construction of variables, the available sample runs from 1960:2 to 1997:2. The additional observations contain some interesting data variation, including several large movements in oil prices and very low rates of unemployment, in addition to eight more degrees of freedom.

The analysis in this paper also uses the Fed Funds rate rather than the 3-month Treasury bill rate, in order to more directly associate money market conditions with monetary policy. The qualitative results are very similar to those using the T-bill rate.

B. Re-specifications

Mork (1989) was the first to note that the addition of data from the 1980s weakened the 'oil Granger causes output' result and to propose a new specification that better fit the data.[3] Working with the GNP equation of Hamilton's VAR and a modified oil price series, Mork showed that the *p*-value for the hypothesis 'oil prices do not Granger cause output' fell to borderline significant (.071) when the dataset was extended through 1988:2 (.14 with Hamilton's original oil price), and that the equation failed a Chow test for structural stability across 1986:1/86:2. When oil price increases and decreases were entered separately, the coefficients on oil price increases were significantly different from those on price decreases, the VAR was structurally stable across that breakpoint, and price increases Granger-caused output changes while price decreases did not (*p*-values of .001 and .152). Mork did not advance a theoretical explanation for why oil price increases and price decreases would have asymmetric effects.

Mork's raw oil price is the producer price index for crude oil in log differences (Hamilton's series) before 1972, switching over to log differences of the 'refiner's acquisition cost, composite' series from the *Monthly Energy Review* in the early 1970s to correct for domestic price controls (see Mork (1989) for details). His transformation is simply to set values less than zero (price decreases) equal to zero; in the analysis below the series has been extended to 1997:2 and given the mnemonic MOPU.

Ferderer (1996) examined the hypothesis that oil prices affect the economy via a sectoral shifts transmission mechanism (Lilien 1982, Loungani 1986), whereby oil price changes in either direction induce costly sectoral reallocations of resources, or an investment-uncertainty mechanism (Bernanke 1983, Pindyck 1991), whereby increased uncertainty increases the option value of waiting and leads to delayed investment. His proxy for the sectoral shifting and

---

[3] Hamilton (1983) found that the *p*-value for oil prices Granger-causing output fell from .0005 to .003 in the 1973:1-80:3 period vs. 1949:2-72:4, and a corresponding drop in the impulse-response function to about half its earlier magnitude. Burbidge and Harrison (1984), using data through 1982, found the influence of oil prices in the second OPEC shock on industrial production to be quite small. Neither paper proposed another specification.

uncertainty that oil prices generate is a weighted within-month standard deviation of daily spot prices of different petroleum products.

Ferderer compared the predictive power of this oil price volatility measure to that of oil price levels and of monetary policy (nonborrowed reserves or the Federal funds rate), in monthly four-variable VARs. He found that oil price volatility Granger caused industrial production at the 1% level in the VAR with nonborrowed reserves, and in the VAR with the Fed funds rate as long as the oil price change is excluded (due to multicollinearity), using a sample period of 1970 through 1990 (the period for which the daily oil price observations were available).

Given the focus of this paper on behavior of the equations at various points of the sample, we use an approximation to Ferderer's variable that is available earlier than 1970 and after 1990. Constructed as the standard deviation of the three monthly real crude oil PPI values within the quarter and denoted OILVOL, it has the disadvantage of using only three datapoints to construct each volatility observation, but the advantage of availability over the full 1960-97 sample period.

Lee, Ni, and Ratti (1995) (hereafter, LNR) argued that "an oil shock is likely to have greater impact in an environment where oil prices have been stable than in an environment where oil price movement has been frequent and erratic" (p. 42). They view the conditioning on volatility as a permanent/transitory distinction: price changes in a volatile environment are likely to be soon reversed. While they did not discuss an economic mechanism which distinguishes between the effects of expected and unexpected price changes, they showed that most oil price changes are unanticipated (the levels series is highly autoregressive), so that empirically it is unlikely to matter much which is used. LNR estimated a GARCH model of oil prices and used it to extract the unanticipated component and the time-varying conditional variance of oil price changes. Their ratio, "scaled oil price surprises," is the basic oil price transformation, which LNR further divide into positive and negative components.

LNR found that the positive part of the scaled oil price surprise very significantly Granger caused both output and unemployment (with *p*-values rounding to 0.000) in samples running from 1950 through 1986, 88, and 92, while the negative part was never significant. This oil price specification dramatically outperformed both Hamilton's original and Mork's positive/negative specification. They interpreted the significance of the positive and insignificance of the negative components as being supportive of sectoral reallocation and/or investment-uncertainty mechanisms in conjunction with conventional symmetric responses: like Mory (1993) and Ferderer (1996), they reason that the effects reinforce one another when prices rise and largely offset each other when prices fall. Here we follow LNR in constructing a scaled, positive oil price surprises series by fitting a GARCH model to real oil price changes and taking the positive component of the residuals divided by their conditional standard deviation; it is given the mnemonic LNRU.

The final oil price transformation that we examine was proposed by Hamilton (1996a), who also advocated an investment-uncertainty transmission mechanism. He argued that "[i]f one wants a measure of how unsettling an increase in the price of oil is likely to be for the spending decisions of consumers and firms, it seems more appropriate to compare the current price of oil with where it has been over the previous year rather than during the previous quarter alone" (p. 216). Specifically, his "net oil price increase" transformation equals the percentage increase over the previous year's high if that is positive, and zero otherwise. This creates a series which is similar to MOPU until 1986 (when price increases were infrequent they usually set new annual highs), but filters out many of the small choppy movements since then. It also explicitly rules out effects from price decreases.

Hamilton (1996b) found support for this specification using nonparametric kernel methods. He showed that it renders the equations stable across breakpoints, and Granger causes output in the post-1973 sample in bivariate and trivariate (including the Fed Funds rate) VARs, although not in the 5-variable VAR of Hooker (1996). The net oil price increase analyzed in this paper is constructed as described above from the extended raw Mork series and denoted NOPI.

III. Does Misspecification Explain the Breakdown?

A specification that successfully represents the oil price-macroeconomy relationship ought to pass structural stability tests and Granger cause output and unemployment in most subsamples. This section evaluates how well the proposed re-specifications perform in such tests using modifications of the basic VARs from Hooker (1996), described in footnote 1 and section II.A. Eight lags are used in the stability tests and six in the rolling regressions.

A. Structural Stability Tests

In considering the stability of oil price-macroeconomy VARs, there are several potential breakpoints of interest: 1973 when OPEC began to dominate the market, 1981 when prices began falling, 1986 when the market collapsed and then became much more volatile, and possibly others. While several authors have performed stability tests across one of these particular points with one or two oil prices, it is desirable to conduct a more thorough and systematic set of tests.

One way of dealing with the uncertainty about when a break might have taken place is to construct tests using all of the points in the interior of the sample as possible breakpoints. This approach has two advantages. First, distribution theory is available, so a formal test of the hypothesis that a structural break with an unknown change point took place can be performed. The second is that one can visually inspect the individual test statistics to let the data show where breaks are most likely to have taken place. While this does not constitute a formal test, it may be helpful in identifying the shortcomings of a specification, e.g. if indicated breaks coincide with known changes in the behavior of oil prices or in other related series.

To compute these structural stability tests, the VARs are estimated allowing different oil price coefficients before and after each potential breakpoint in the middle 70% of the sample (between 1967:2 and 1992:1). The other coefficients are kept fixed; the intercepts in the two subsamples are not constrained to allow for secular change in the output growth rate or unemployment rate. The maximal Wald statistic from this set of tests, recorded in part A of Table 1, may be compared to the appropriate asymptotic critical value in Andrews (1993); 8 coefficients are allowed to change over the (.15, .85) section of the sample so the 10%, 5%, and 1% critical values are 19.82, 22.13, and 27.25. Figures 2a-d plot p-values from F-tests of the hypothesis that there is not a structural change in the oil price coefficients, for every potential breakpoint for the four proposed oil prices.

The test results using Mork's increases-only variable, MOPU, strongly support a structural break in the unemployment equation and weakly support one in the output equation. The maximal Wald tests reject stability at the 1% and 10% levels, respectively. Figure 2a shows that test statistics for the unemployment equation exceed 5% critical values for *any* breakpoint in the 1974-87 period, and 1% critical values for all points between 1975 and 1980. The output equation appears to be more stable, but has numerous points where the Chow test statistic exceeds its 10% critical value. Chow-test statistics fall (the p-values rise) rapidly after 1986 in both equations, suggesting that it is the contrast between the pre- and post-1986 data that provides most of the evidence for a break.

Andrews tests with the OILVOL variable reject stability of the both the output and unemployment equations at the 1% level. Figure 2b shows that the equations with OILVOL also strongly support breaks anywhere within the 1975-80 period. Interestingly, the OILVOL equations do not display the pre/post 1986 contrast that the MOPU equations do.

The unemployment equation with Lee, Ni and Ratti's positive scaled oil price surprises variable (LNRU) appears stable in Figure 2c, and indeed it passes the maximal Wald test at the 10% level. In the output equation, a Chow test would fail to reject at nearly all of the potential breakpoints, with the exception of the 1972-74 period, but the maximal Wald test rejects at nearly the 1% level. Since Andrews's test is based on the maximal test statistic observed, it does not distinguish a case like in Figure 2c from one like Figure 2a, where far more potential breakpoints would generate statistics rejecting stability. Therefore, while one might not want to use the output-LNRU equation in full-sample analysis without allowance for a breakpoint, a single dummy variable might take care of it, and subsample analysis confined to post-74 data might yield valid inferences. Like the OILVOL equations, the LNRU equations do not display any pre/post 1986 contrast in stability.

The unemployment equation with Hamilton's net oil price increase (NOPI) variable shows strong evidence of a break throughout the 1975-80 period, and generates a maximal Wald statistic which rejects at the 1% level. The output equation appears to be nearly stable in Figure 2d, with just two brief forays of Chow test p-values below 10%, although one of these is sufficient for the Andrews test to reject at the 10% level. Again there is little contrast between the pre- and post-1986 Chow test statistics.

Overall, the unemployment equations with the exception of the LNRU case are quite unstable, while the output equations exhibit less pronounced and more localized instability. The three oil price specifications that incorporate measures of volatility, OILVOL, LNRU and NOPI, seem to have dramatically reduced the influence of pre- and post-1986 data on the stability of the equations, as indicated breakpoints are all in the 1970s. These results suggest that the respecifications have made progress in resolving the breakdown, but recommend caution in interpreting full-sample oil price-macroeconomy VAR estimates and tests.

B. Robustness with Respect to Sample Period

The evidence documented in the previous subsection implies that the oil price-macroeconomy relationship may change significantly over the postwar period even within the proposed respecifications. This argues against analyzing fixed-beginning rolling regressions like those presented in Figure 1, which can otherwise be informative since only the newly included data is associated with changing test results.[4] Instead, in order to use more homogenous samples and still allow tests to be computed across different parts of the sample, I roll both the start and end points of the sample forward, keeping the sample size fixed. These tests use six lags rather than eight, using 90 quarters of data to estimate 31 parameters in the unconstrained regression. The first sample runs 1961:4-84:1 and the last 1975:1-97:2; *p*-values from these tests are plotted in Figures 3a-d.

The first two of the four candidate oil price transformations, MOPU and OILVOL, fail to Granger cause output and unemployment in virtually all of the subsamples. This is in sharp contrast to the results in Hooker (1996), where these variables were strongly significant in the 1948-73 sample. Since the difference is due to movements in oil prices−all of the samples here include falling oil price data from the 1980s, and most include volatile post-1986 data as well−these respecifications do not seem to capture the true oil price-macroeconomy transmission mechanism.

The second two transformations perform somewhat better, but still fail to Granger cause output in most of the samples. LNRU, the positive, scaled oil price surprises series, Granger causes unemployment in most of the samples, more strongly when data from the 1990s is included. However, it shows little ability to predict output movements until the last few samples. Hamilton's NOPI variable performs similarly: *p*-values for the unemployment equation are often below .10, but those for output are mostly in the .30-.50 range.

The picture that emerges from these tests is that the proposed transformations of oil prices have not restored a robust oil price-macroeconomy relationship in datasets that include the 1980s and 1990s. While the LNRU and NOPI transformations have some success Granger causing the unemployment rate, neither is a robust predictor of output, and both show some signs of

---

[4] Thoma (1994) used that technique to examine puzzles in the money-output causality literature.

structural instability. The next section turns to an assessment of the role of money market interest rates in the oil price-macroeconomy relationship.

IV. Respecifications without Interest Rates

The VARs analyzed in the previous section all contain the Federal Funds rate as a conditioning variable.[5] This section explores the consequences of omitting this variable, which is motivated by two sets of results. The first is the finding of Sims (1980) and many subsequent researchers that short-term interest rates have significant effects on money-causes-output tests, suggesting that they may affect other related tests as well. The second is the robust oil price effects obtained by Carruth, Hooker and Oswald (1997), Daniel (1997), and Hamilton (1996b) in models without short-term interest rates.[6]

The equations' structural stability properties are apparently little affected by the inclusion or exclusion of short term interest rates. Part B of Table 1 shows that the maximal Wald test statistics and significance levels are quite similar to those from the 5-variable VARs in part A of the Table. In particular, the LNR output equation still shows a break with 5% significance, and the NOPI unemployment equation a break at 1%. The full sets of *p*-values (not shown) are also quite similar to the 5-variable VAR cases plotted in Figures 2a-d.

By contrast, the exclusion of short term interest rates has a large effect on the rolling regressions. Here, Granger causality from all four oil prices to output and unemployment is much stronger than when rates are included. The *p*-values are roughly halved in each of the eight cases (four specifications and two equations), bringing many of them below the 5% threshold.

---

[5] Both the structural stability and Granger causality test results are very similar when the 3-month Treasury bill rate is used instead of the Funds rate.

[6] Carruth, Hooker and Oswald showed that real oil prices, in both log levels and differences, Granger cause the unemployment rate in bivariate and trivariate (including a medium term real interest rate) VARs, in data spanning 1973-95 and 1948-95. They also found that simple error-correction models using real oil price levels produce quite good out-of-sample forecasts of unemployment in the early 1990s. Daniel found that industrial production in the U.S., U.K., and Japan share a common trend with real oil prices in data from 1960-92 using a Johansen-cointegration approach. Much of the support for NOPI found by Hamilton (1996) is in bivariate VARs with output.

As suggested by Figures 3a and 3b, this is not enough to render MOPU and OILVOL robust predictors of activity. Mork's up-only variable performs reasonably well in samples through 1987, but still shows an inability to capture the relationship between oil prices and either output or unemployment in post-1990 data. The volatility measure behaves similarly, doing slightly worse in the 1980s but better in the 1990s. Neither variable achieves Granger causality of output and unemployment at conventional significance levels in a majority of sample periods.

LNRU and NOPI perform substantially better. The former Granger causes unemploy-ment at or below the 10% level in all samples, and output in samples that end after 1991; *p*-values are between .10 and .20 for earlier samples. Hamilton's net oil price increase Granger causes both output and unemployment at the 5% level or better in the vast majority of sample periods.

These results suggest that the severely diminished ability of oil prices to predict macroeconomic activity since 1986, illustrated in Figure 1, is due to incorrect functional form *and* the interaction of oil prices with money markets. With respect to specification, it appears that incorporating aspects of volatility and asymmetry−with Hamilton's NOPI specification the leader of the current contenders−is important. The next section attempts to disentangle the effects of oil prices and short term interest rates on the macroeconomy, focusing on the NOPI representation and output.

V. Investigation and Interpretation of Results

We may summarize the 'net oil price increase' results as follows. First, the NOPI coefficients change significantly over the sample, whether or not interest rates are included in the VARs. Second, the output equation coefficients are significantly different from zero in pre-1974 data that include interest rates (Hamilton 1996b), but in more recent data they are significant only if interest rates are excluded. The unemployment equation coefficients are generally significant. How should we interpret this evidence? I first examine the output Granger causality results with impulse-response functions, which can provide more information than one-dimensional *F*-statistics, and then discuss unemployment and stability issues.

Figures 5a-d plot the orthogonalized responses of output to NOPI with and without including an interest rate in the VAR, in pre- and post-1973 data. The variable ordering goes output, inflation, import inflation, oil price, interest rate; thus oil prices are placed after everything but interest rates to be conservative, interest rates respond to contemporaneous oil prices but not vice-versa, and output is assumed not to respond to the interest rate within the quarter. In the 1948-73 sample, the VAR is as in footnote 1 (it uses the old GDP accounts data and the 3-month Tbill rate, as the Funds rate is not available before 1954). The second sample runs 1974:1-97:2, and is as described in section IIA.

Figures 5a and 5b show the responses of output growth to a one-standard deviation NOPI shock, estimated on the 1948-73 sample excluding and including the Tbill rate. The response functions and the precision with which they are estimated are both quite similar (dotted lines show two asymptotic standard errors). Output growth is predicted to be about 3/4 of a percentage point lower in the year following the shock, and then actually higher in the second year. The decrease is strongly, and the increase marginally, statistically significant.

Figures 5c and 5d make the same comparison with responses estimated on the 1974-97 sample. Both responses are smaller than their pre-73 counterparts, and the responses are flat after the first year, in contrast to the cyclical swings found with the earlier data. The response with the Funds rate excluded, shown in Figure 5d, is still significant at lags 1, 3, and 4, while the response with the rate included is only marginally significant at lags 1 and 3.

Why does inclusion of the Fed Funds rate now reduce the size and significance of the output responses? One possible explanation is that oil prices and short-term interest rates now move closely with one another, so that either one has reduced significance in the presence of the other.[7] Indeed, several authors, including Boschen and Mills (1988), Dotsey and Reid (1992) and Hoover and Perez (1994) have found that money market interest rates and other measures of monetary policy do not Granger cause output in the presence of oil prices. Figure 6a confirms that the Federal Funds rate fails to Granger cause output in VARs that include NOPI in most subsamples, while the results are stronger for unemployment—just as they are in the oil price case (Figure 3d).

Oil prices appear to be exogenous in both historical evaluation (Hamilton 1985) and Granger causality tests (Hamilton 1983, Hooker 1996), while money market variables are commonly

---

[7] Contemporaneous correlations between NOPI and the Fed Funds rate seem anomalous with a multicollinearity explanation of the Granger causality results: the correlation is only .32 over the full 1960:2-97:2 period; moreover it is higher (.40) in the 1960-73 subsample and lower (.13) over 1982-97, although it rises back to .32 over 1986-97. The VARs have 6 or 8 lags, so lead-lag relationships are important; the impulse-response functions in Figure 5 suggest that these differ considerably from the contemporaneous relationships.

understood to contain a large endogenous component. Therefore, a likely explanation is that oil price shocks induce Funds rate movements. If such a pattern began with the OPEC shocks, as seems reasonable, that might explain how conditioning on interest rates made little difference in pre-1973 data but is now important. Ferderer (1996) and Bernanke, Gertler and Watson (1997) found evidence that oil price shocks affect the economy both directly and indirectly through Fed tightenings, in datasets spanning 1970-90 and 1965-95, respectively.

I find some evidence for this hypothesis. While NOPI does not Granger cause the Funds rate in the 1974-97 sample, it does over many earlier samples. Repeating the 90-observation rolling tests with the Funds rate as the dependent variable, Figure 6b shows that it responded significantly in nearly all samples through 1992, and impulse-response functions (not shown) indicate that oil price increases were indeed followed by tightenings.

Something in that relationship appears to have broken down in recent years, however. While with only five years of data it is difficult to identify what might have changed in the relationship between NOPI and the Funds rate, the macroeconomic data over this period (1992-97) suggest that the possibility of misspecification should be given close consideration: the Fed may not be responding to NOPI because it no longer accurately represents the state of the oil market. This explanation would also be consistent with the subsample instability found in sections III and IV.

One likely source of misspecification is that NOPI, like LNRU and MOPU, rules out any effects from price decreases. Ignoring price decreases would seem to court fragility, since its theoretical rationale is that separate contractionary and expansionary effects happen to roughly cancel each other out, and cancellation is unlikely to be robust across price declines of different size, permanence, and predictability, and in economies with different sectoral compositions, imported energy dependencies, etc.

There have been several large oil price decreases in recent years, some of which seem to correlate with increases in output. Prices fell nearly in half at the beginning of 1991 and stayed low for the rest of the year, and output grew at a robust 3.5% in 1992. Oil prices also fell sharply in mid-1993 and early 1994, and 1994 growth was again above average. In addition, there were two quarters of oil price increases in 1996 that came through the Hamilton filter at 10% each, suggesting by the impulse-response functions in figures 5c and 5d that output growth is now nearly a percentage point *per quarter at annual rates* lower than it otherwise would be.

It is hard to believe that we would now be experiencing 5% growth if it were not for those shocks;[8] perhaps the 10% price drop in 95:3 partially offset them.

It would also seem that arguments discounting expansionary effects of the 1986 oil market crash are questionable. Both Mork (1994) and Ferderer (1996) have argued that the dramatic price decreases (from a refiner's acquisition cost of $26.90/bbl in November 1985 to $11.50 in July) support asymmetry because there was no boom in that year, but this ignores the historical four- to eight-quarter lag between oil price movements and peak macroeconomic responses. In fact, the latter half of 1987 saw very strong real growth, high levels of capacity utilization, and substantial reductions in unemployment.[9]

A final concern is the contrast between the output and unemployment results. Oil prices, as measured by NOPI or LNRU, generally Granger cause the unemployment rate whether or not the Funds rate is included in the equation, and the Funds rate causes unemployment with or without oil prices. Thus the multicollinearity/monetary policy response story is inconsis-tent with Okun's law, and warrants further investigation.

VI. Summary and Conclusions

This paper analyzes the relationship between oil prices and macroeconomic activity in VAR systems, with a focus on recent efforts to reestablish a robust link by respecifying the oil price. It finds that the original specifications of the oil price−in log levels or differences−break down quite suddenly when data from the 1980s is included. While some authors like Cochrane (1994) interpret subsequent low levels of significance as evidence that oil prices don't matter much for the macroeconomy, the abruptness of this change, and its correlation with the state of the oil market, make that unlikely. Rather, the dramatic fall in oil prices and increase in volatility around this time suggest that misspecification is an important part of the explanation.

---

[8] In terms of unemployment, the implication is that without the 1996 price increases the rate would now be in the low 4% range.

[9] Ferderer (1996) has also argued that the volatility explanation of asymmetry, where movements in either direction are contractionary, is supported by the fact that the one postwar recession (April 1960-Feb. '61) not preceded by an oil price increase followed price drops. However, these drops were only 12% and 6% at annual rates, and so could explain only a small fraction of the recession.

The paper evaluates four recent respecifications with structural stability and rolling-sample Granger causality tests. It finds that two of the respecifications, Lee, Ni and Ratti's positive oil price surprises scaled by volatility and Hamilton's net increase, produce significant improvements in predicting unemployment. However, the improvements in predicting output are not sufficient to achieve Granger causality at conventional significance levels in a majority of samples that include post-1986 data with an interest rate in the VAR. If the interest rate is excluded, then the net oil price increase (NOPI) Granger causes output and unemployment in all samples with high degrees of confidence.

One explanation for this dependence on the interest rate is that oil prices, since the 1970s, partly affect the macroeconomy directly and partly indirectly by inducing monetary policy responses. Multicollinearity thus reduces the significance of oil prices or of the Funds rate when the other is present in the regression. The paper finds some support for this explanation. The Funds rate is symmetric with oil prices in not Granger causing output in the presence of NOPI, and increases in NOPI induce significant monetary tightenings in samples up through 1992 but not later. There is no evidence to support Bohi's (1991) allegation that exogenous oil prices are merely proxying for the causal, yet endogenous interest rates.

The Granger causality results with unemployment are different but still symmetric: NOPI Granger causes unemployment whether or not the Funds rate is included, and the Funds rate Granger causes unemployment whether or not NOPI is included. This difference between the output and unemployment results is puzzling and deserves futher investigation.[10]

The structural instability in all of the equations, and the failure of NOPI to Granger cause the Funds rate in recent data, both suggest that some misspecification remains in the NOPI representation of oil market effects. While the two distinguishing characteristics of the specifications which provide substantial improvement are incorporation of volatility and ruling out of price decreases, there is some evidence that further refinement is required with respect to the latter.

---

[10] Studies of oil price effects on the labor market at the microeconomic level, like Keane and Prasad (1996), Davis, Loungani and Mahidhara (1996), and Davis and Haltiwanger (1996), may be helpful in this regard. It should be noted that these micro studies tend to find very strong effects from oil prices, measured in various ways.

What do we learn about the mechanism(s) by which oil prices affect the economy from the evidence in this paper? To the extent that the LNR and Hamilton specifications are successful, they support a two-channel structure. For oil price decreases to have little effect, there must be offsetting responses. Leading theoretical explanations of the contractionary channel (in response to oil price increases and decreases) are sectoral shifts, where important changes in relative prices lead to costly reallocation of resources across sectors (measured as reduced output and employment), and investment-uncertainty, where firms and households postpone investment due to the higher option value of waiting during periods of turbulence. Unfortunately, these are difficult to distinguish empirically. The symmetric channel could be real balance effects from oil price effects on the price level, impacts on output capacity, or wealth effects from the terms of trade.[11]

---

[11] While this last explanation was popular in many discussions of the late 1970s and early 1980s, it has not stood up well to the data. Mork, Mysen and Olsen (1994) and Carrruth, Hooker and Oswald (1995) found that Britain and Canada, both oil exporters, have had similar responses to oil price shocks as have oil importers. Mork, Mysen and Olsen did find that Norway, with a considerably higher degree of concentration in oil, benefits from price increases and is hurt by price decreases; this result also tends to hold for a few states in the U.S. like Alaska, Oklahoma and Wyoming.

Data Appendix

The data used in this study, the source, and any transformations are as follows. Data is available on request.

Federal Funds rate: from the Federal Reserve Economic Data database (FRED) at the St. Louis Federal Reserve Bank, aggregated from monthly to quarterly using the middle month of the quarter.

Inflation: GDP Chain-type Deflator, from FRED, seasonally adjusted, entered as 400* log first difference.

Import Price Inflation: ratio of nominal to chained 1992 dollars' imports, NIPA accounts, from FRED, seasonally adjusted, entered as 400* log first difference.

Unemployment rate: civilian age 16 and over rate, seasonally adjusted, from FRED, aggregated from monthly to quarterly using the middle month of the quarter.

Real GDP: in chained 1992 dollars, from FRED, seasonally adjusted, entered as 400* log first difference.

MOPU Oil price: through 1972, 400* log first difference of the Crude Oil PPI (BLS series WP0561), aggregated using middle month of quarter. From 1974, the same transforma-tion applied to the DOE composite domestic first purchase price (ftp.eia.doe.gov). Intervening quarters are the growth rate of the PPI multiplied by 1.095 (see Mork (1989). Negative observations set to zero.

OILVOL Oil price: the simple standard deviation of the PPI for crude oil for the three months of each quarter, BLS series WP0561.

LNRU Oil price: a GARCH (1,1) model was fitted to Mork's series (including negative observations) less the inflation rate above. LNRU is the nonnegative residuals from this equation divided by their conditional variance.

NOPI Oil price: equals the percentage change in Mork's levels series from the past four quarters' high if that is positive, and zero otherwise.

REFERENCES

Andrews, Donald W. K., "Tests for Parameter Instability and Structural Change with Unknown Change Point," *Econometrica* 61 (1993), 821-56.

Bernanke, Ben S. "Irreversability, Uncertainty, and Cyclical Investment," *Quarterly Journal of Economics* 98 (1983), 85-106.

_______, Mark Gertler, and Mark Watson, "Systematic Monetary Policy and the Effects of Oil Price Shocks," *Brookings Papers on Economic Activity* 1:1997, 91-142.

Bohi, Douglas R., "On the Macroeconomic Effects of Energy Price Shocks," *Resources and Energy* 13 (1991), 145-62.

Boschen, John F. and Leonard H. Mills, "Tests of the Relation Between Money and Output in the Real Business Cycle Model," *Journal of Monetary Economics* 22 (1988), 355-74.

Burbidge, John and Alan Harrison, "Testing for the Effects of Oil-Price Rises using Vector Autoregressions," *International Economic Review* 25 (1984), 459-84.

Carruth, Alan A., Mark A. Hooker and Andrew J. Oswald, "Unemployment, Oil Prices, and the Real Interest Rate: Evidence from Canada and the U.K.," *in*: L.N. Christofides, E.K. Grant, and R. Swadinsky, eds., *Aspects of Labour Market Behaviour: Essays in Honour of John Vanderkamp* (University of Toronto, Toronto), 1995.

_______, "Unemployment Equilibria and Input Prices: Theory and Evidence for the United States," forthcoming, *Review of Economics and Statistics*.

Cochrane, John H., "Shocks," *in*: Allan Meltzer and Charles Plosser (eds.), Carnegie-Rochester Conference Series on Public Policy 41 (1994), 295-364.

Daniel, Betty C., "International Interdependence of National Growth Rates: A Structural Trends Analysis," *Journal of Monetary Economics* 40 (1997), 73-96.

Davis, Steven J. and John Haltiwanger, "Driving Forces and Employment Fluctuations: New Evidence and Alternative Interpretations," manuscript, 1996.

Davis, Steven J., Prakash Loungani, and Ramamohan Mahidhara, "Regional Labor Fluctu-ations: Oil Shocks, Military Spending, and other Driving Forces," manuscript, 1996.

Dotsey, Michael and Max Reid, "Oil Shocks, Monetary Policy, and Economic Activity," *Federal Reserve Bank of Richmond Economic Review* 78 (1992), 14-27.

Ferderer, J. Peter, "Oil Price Volatility and the Macroeconomy," *Journal of Macroeconomics* 18 (1996), 1-16.

Hamilton, James D., "Oil and the Macroeconomy since World War II," *Journal of Political Economy* 91 (1983), 228-48.

_______, "Historical Causes of Postwar Oil Shocks and Recessions," *Energy Journal* 6 (1985), 97-116.

_______, "This is What Happened to the Oil Price-Macroeconomy Relationship," *Journal of Monetary Economics* 38 (1996a), 215-20.

_______, "Analysis of the Transmission of Oil Price Shocks Through the Macroeconomy," manuscript, UCSD, 1996(b).

Hooker, Mark A., "What Happened to the Oil Price-Macroeconomy Relationship?," *Journal of Monetary Economics* 38 (1996), 195-213.

Hoover, Kevin D. and Stephen J. Perez, "Post hoc ergo propter hoc once more: An evalaution of 'Does monetary policy matter?' in the spirit of James Tobin," *Journal of Monetary Economics* 34 (1994), 47-73.

Keane, Michael P. and Eswar Prasad, "The Employment and Wage Effects of Oil Price Changes: A Sectoral Analysis," *Review of Economics and Statistics* 78 (1996), 389-400.

Lee, Kiseok, Shawn Ni, and Ronald Ratti, "Oil Shocks and the Macroeconomy: The Role of Price Variability," *Energy Journal* 16 (1995), 39-56.

Lilien, David, "Sectoral Shifts and Cyclical Unemployment," *Journal of Political Economy* 90 (1982), 777-93.

Loungani, Prakash, "Oil Price Shocks and the Dispersion Hypothesis," *Review of Economics and Statistics* 58 (1986), 536-39.

Mork, Knut Anton, "Oil Shocks and the Macroeconomy When Prices Go Up and Down: An Extension of Hamilton's Results," *Journal of Political Economy* 97 (1989), 740-44.

_______, "Business Cycles and the Oil Market," *Energy Journal* 15, Special Issue (1994), 15-38.

_______, Øystein Olsen, and Hans Terje Mysen, "Macroeconomic Responses to Oil Price Increases and Decreases in Seven OECD Countries," *Energy Journal* 15 (1994), 19-35.

Mory, Javier F., "Oil Prices and Economic Activity: Is the Relationship Symmetric?," *Energy Journal* 14 (1993), 151-61.

Pindyck, Robert, "Irreversability, Uncertainty, and Investment," *Journal of Economic Literature* 29 (1991), 1110-48.

Sims, Christopher A., "Comparison of Interwar and Postwar Business Cycles: Monetarism Reconsidered," *American Economic Review* 70 (1980), 250-57.

Thoma, Mark, "Subsample Instability and Asymmetries in Money-Income Causality," *Journal of Econometrics* 64 (1994), 279-306.

Table 1: Tests for a Structural Break with Unknown Change Point

A. 5-variable VARs including GDP Deflator, Imports Deflator, and Fed Funds Rate

	RLEV	NDIF	MOPU	OILVOL	LNRU	NOPI
Output Equation	48.92***	39.88***	41.26***	34.90***	18.69	33.97***
Unemp. Equation	19.17	22.99**	22.25**	28.01***	26.05**	19.94*

B. 4-variable VARs including GDP Deflator and Imports Deflator

	RLEV	NDIF	MOPU	OILVOL	LNRU	NOPI
Output Equation	48.45***	41.54***	47.66***	34.86***	17.76	34.73***
Unemp. Equation	20.38*	24.91**	27.72***	34.31***	23.80**	17.31

Notes: Figures in the table are maximal Wald test statistics for a structural break in the oil price coefficients of the VAR's output and unemployment equations. RLEV and NDIF indicate oil prices in real levels and nominal differences. Critical values are 27.25, 22.13, and 19.82 respectively. *, **, *** indicate breaks at 10%, 5%, and 1% levels of significance.

Figure 1: Granger Causality with Standard Oil Price Measures

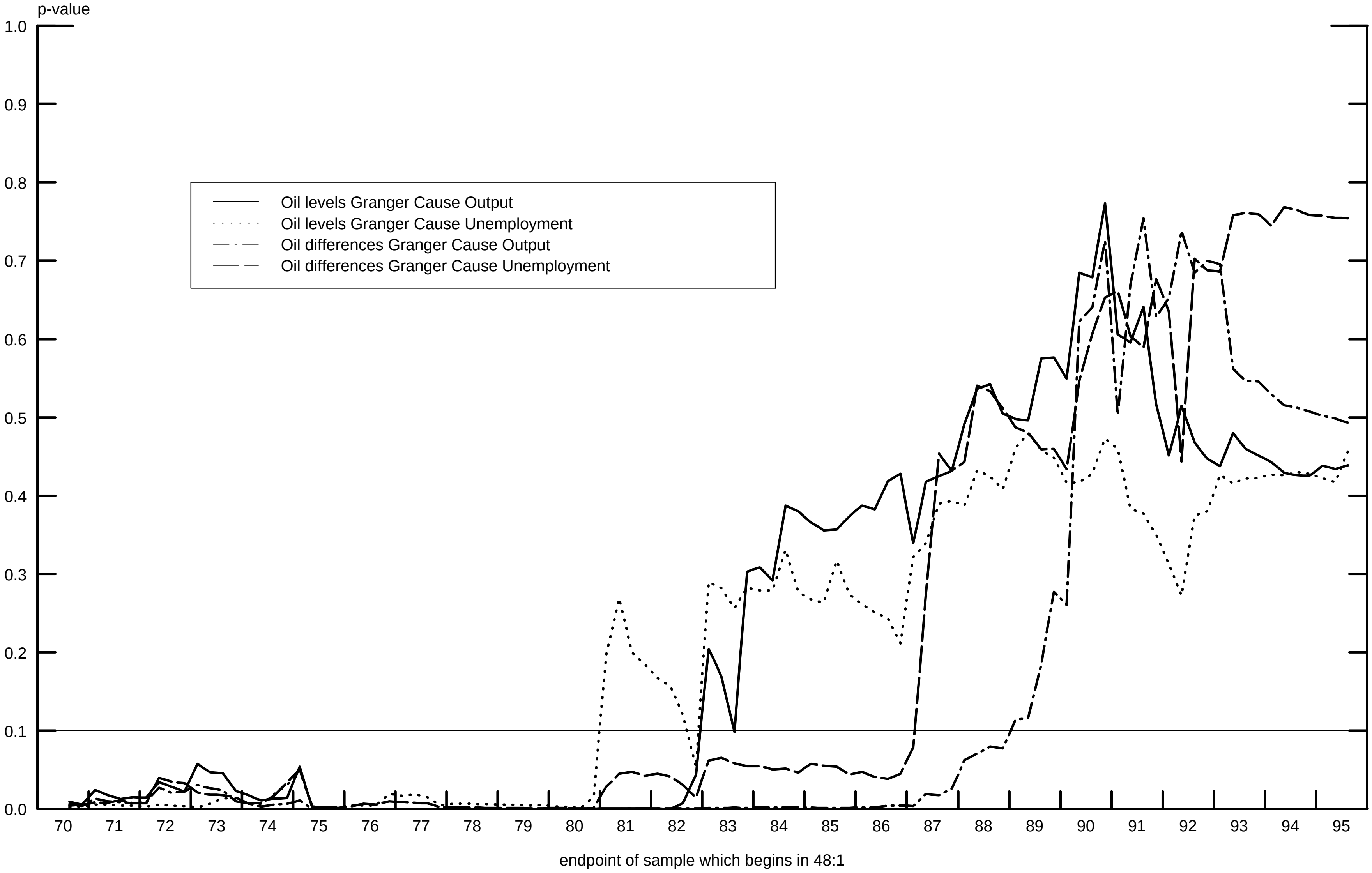

Figure 2a: Structural Stability with MOPU

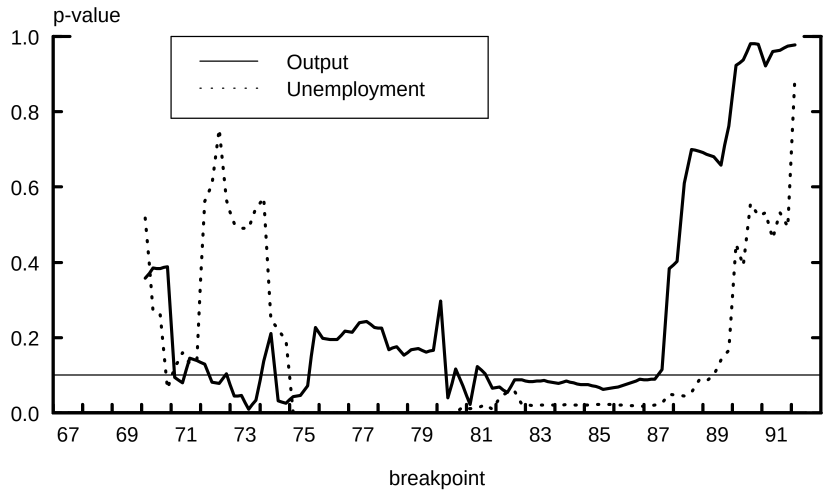

Figure 2b: Structural Stability with OILVOL

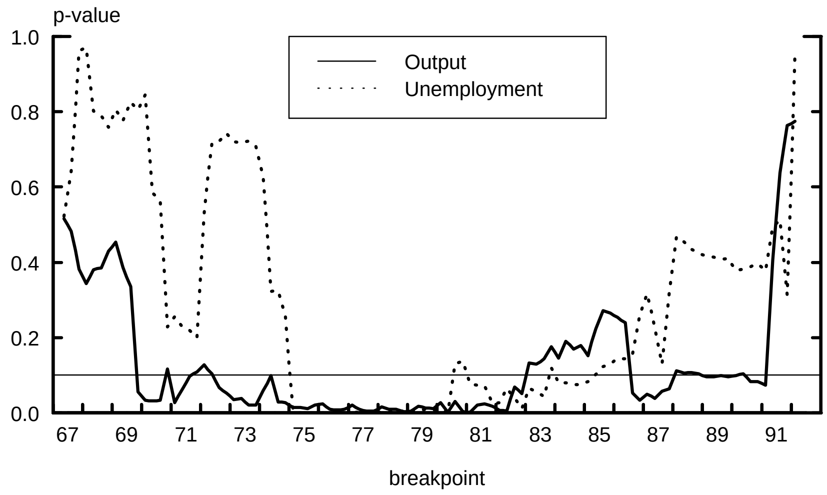

Figure 2c: Structural Stability with LNRU

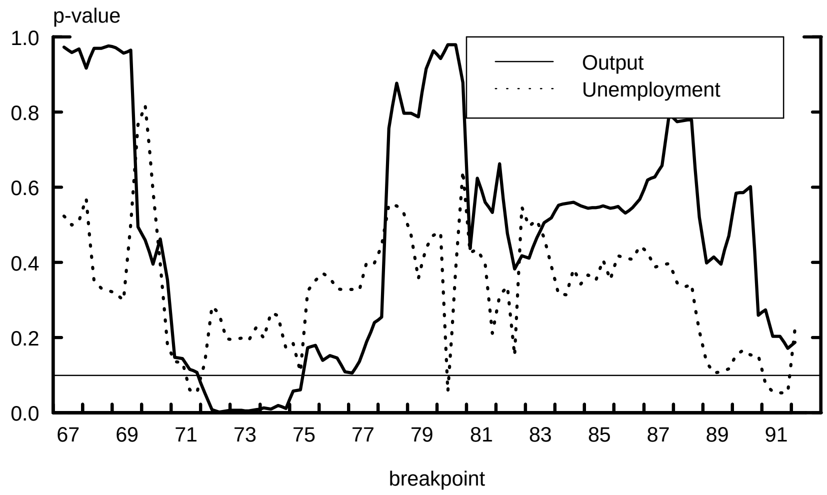

Figure 2d: Structural Stability with NOPI

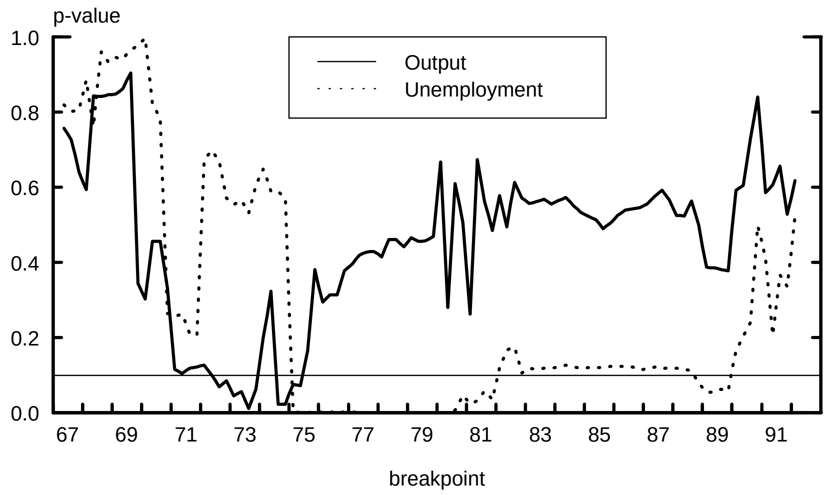

Figure 3a: Granger Causality from MOPU, 5-variable System

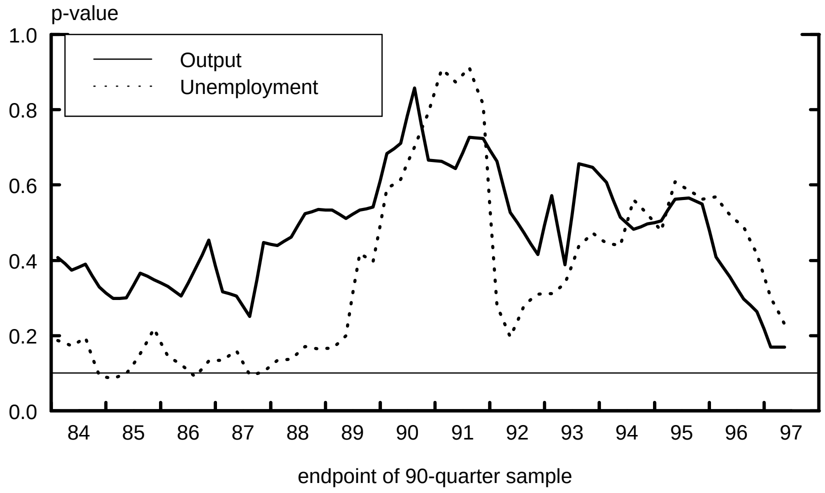

Figure 3b: Granger Causality from OILVOL, 5-variable System

Figure 3c: Granger Causality from LNRU, 5-variable System

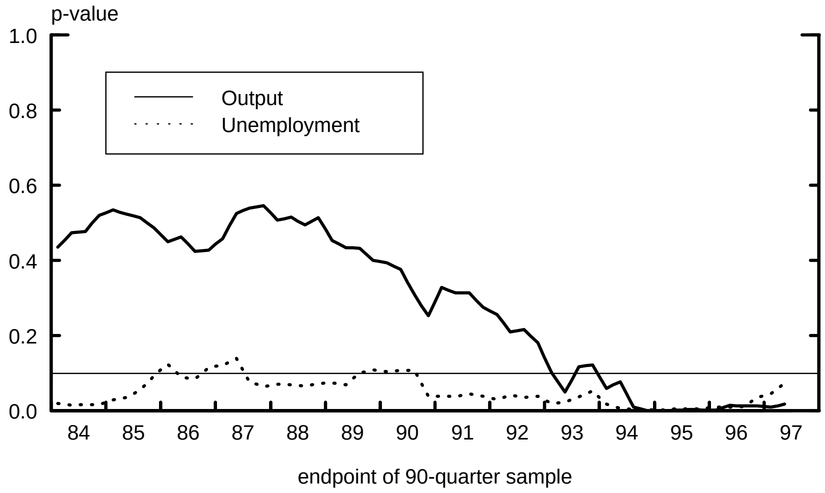

Figure 3d: Granger Causality from NOPI, 5-variable System

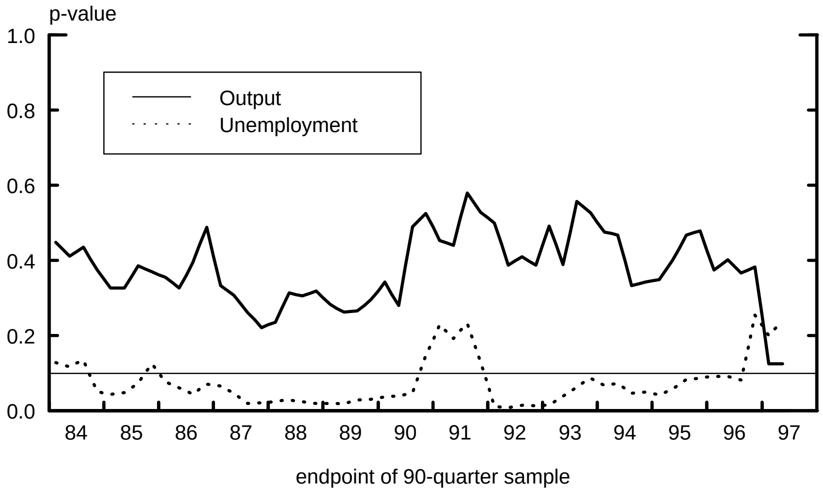

Figure 4a: Granger Causality from MOPU, 4-variable System

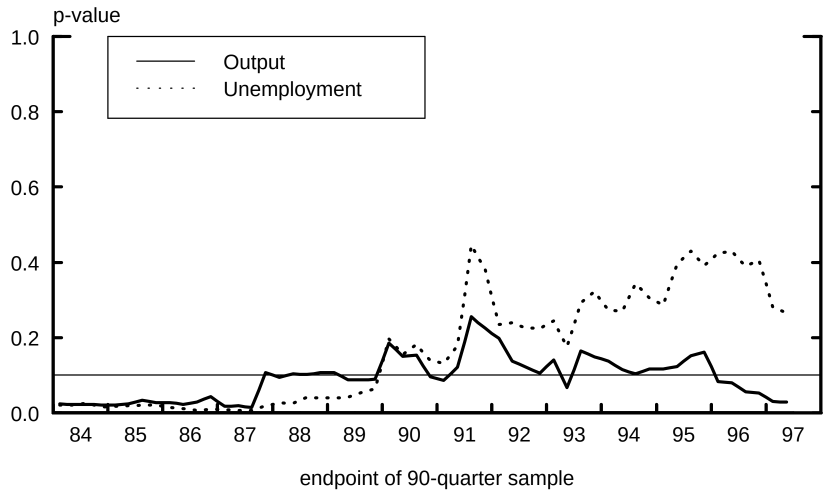

Figure 4b: Granger Causality from OILVOL, 4-variable System

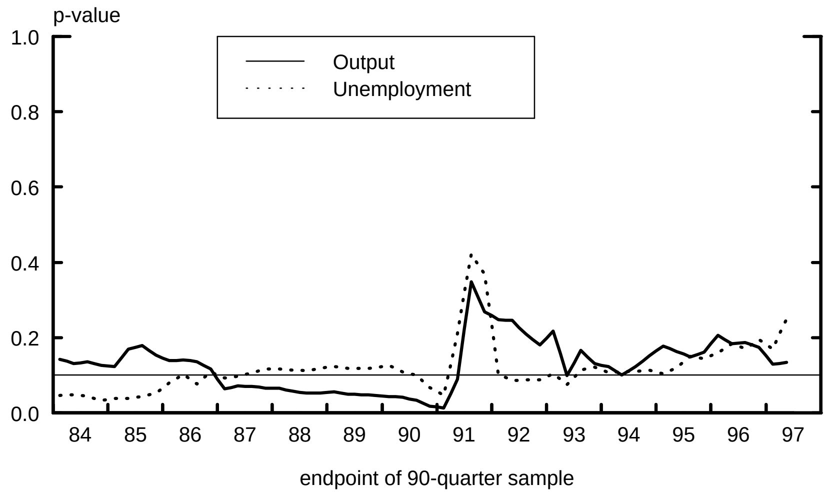

Figure 4c: Granger Causality from LNRU, 4-variable System

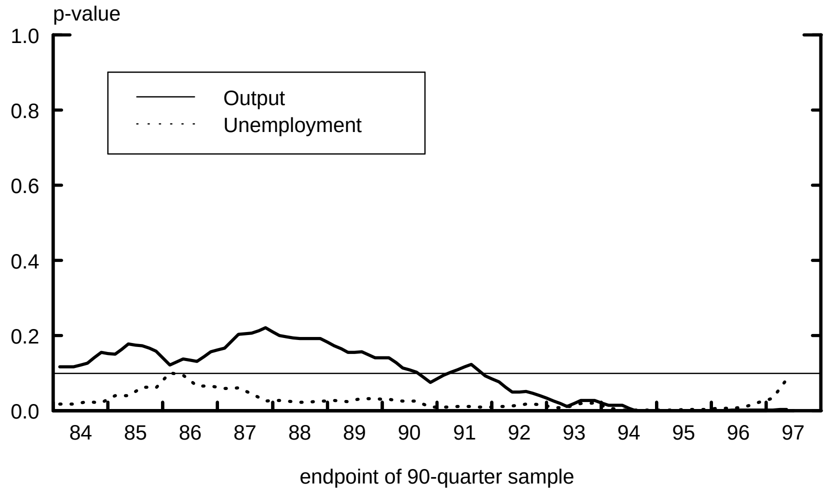

Figure 4d: Granger Causality from NOPI, 4-variable System

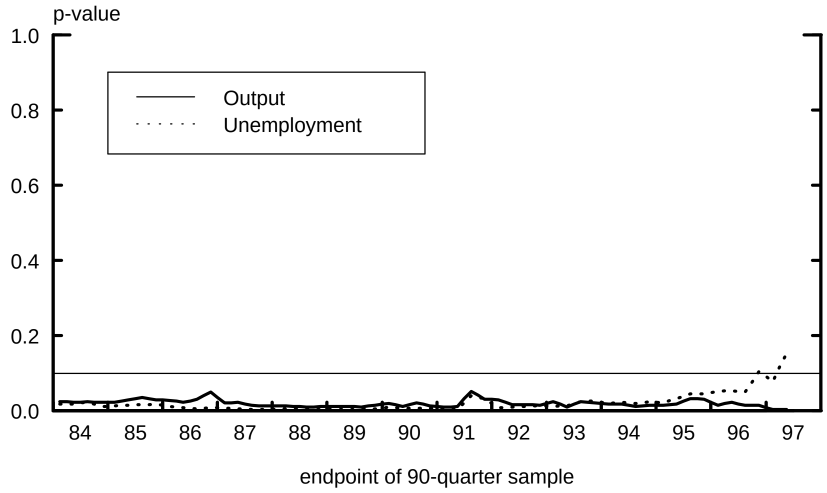

Figure 5a: Response of Output to NOPI, 1948-73 Sample
Treasury bill rate excluded

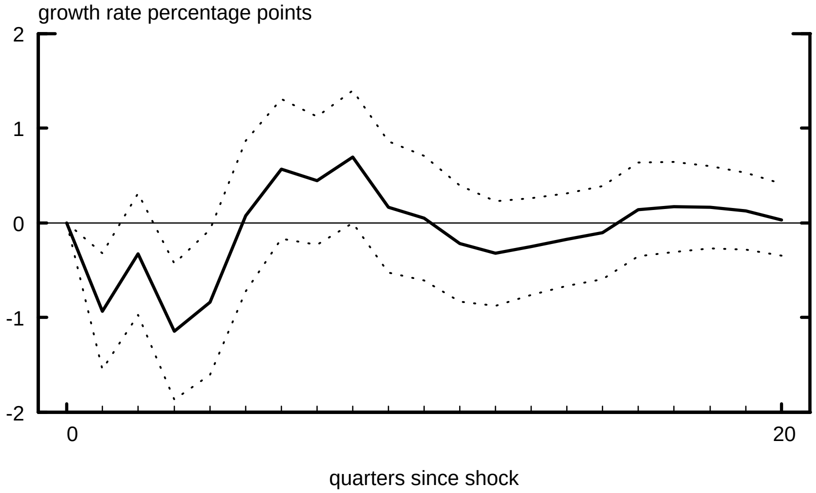

Figure 5b: Response of Output to NOPI, 1948-73 Sample
Treasury bill rate included

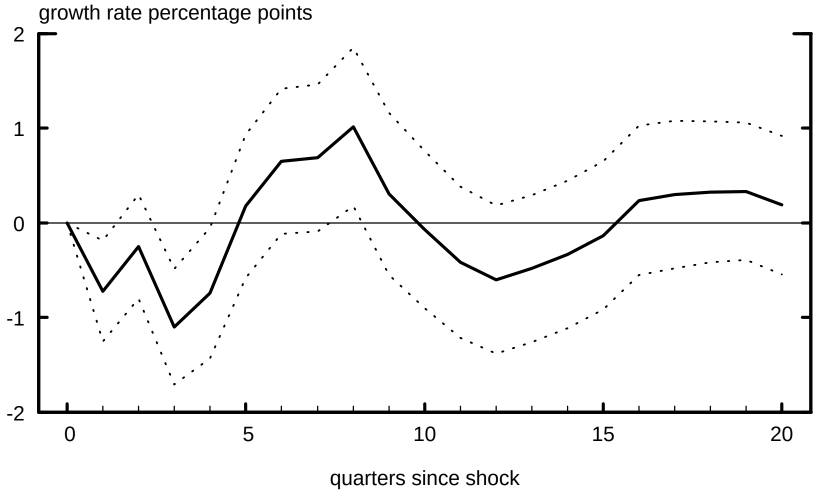

Figure 5c: Response of Output to NOPI, 1974-97 Sample
Fed Funds rate excluded

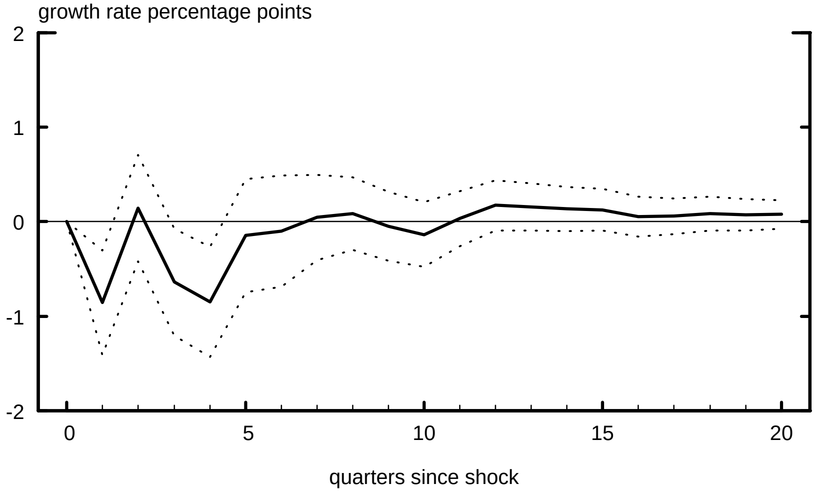

Figure 5d: Response of Output to NOPI, 1974-97 Sample
Fed Funds rate included

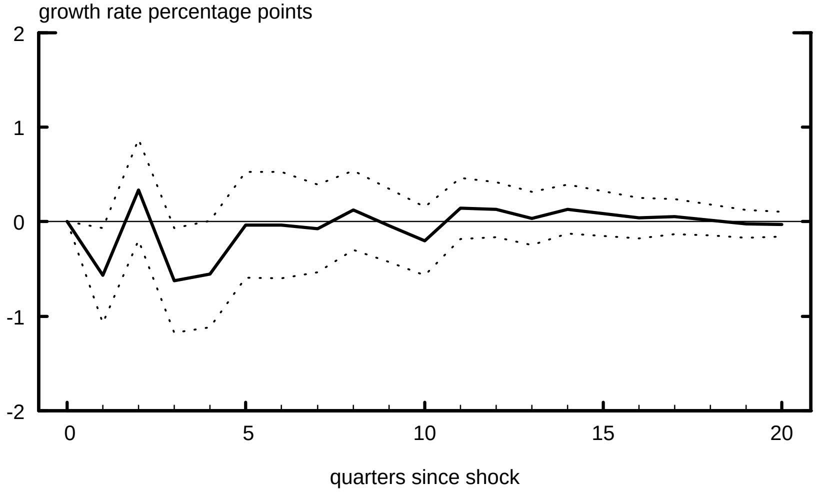

Figure 6a: Granger Causality from Fed Funds with NOPI Oil Price

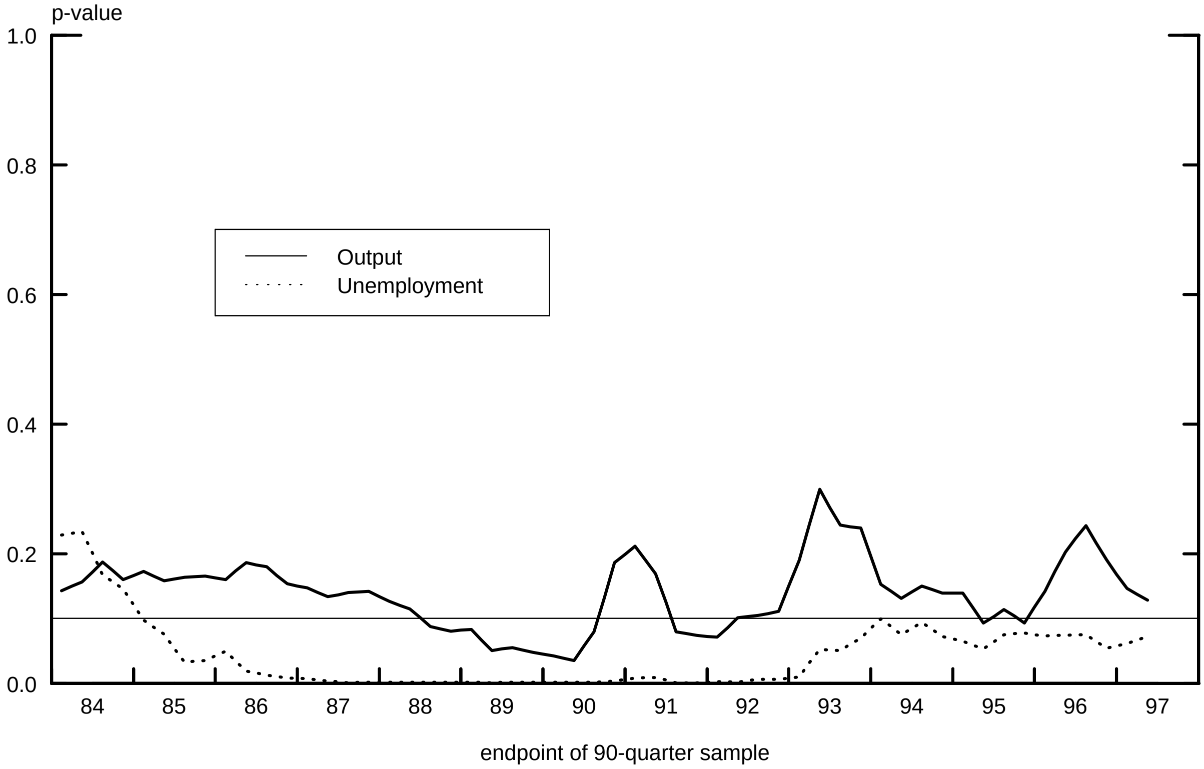

Figure 6b: Granger Causality from NOPI to Fed Funds Rate