Stochastic Trends, Outliers, and State Dependent Effects of Monetary Policy

Thomas Stockwell*

June 5, 2019

Abstract:

This paper investigates whether there are significant differences in the response of US output to monetary policy in expansions and recessions. While much of the existing literature has found that monetary policy is more effective in recessions, a recent influential paper that found the opposite has left the literature with a lack of consensus. While my baseline model agrees with the result that monetary policy is more effective in expansions, this is not robust to the frequency of data and measure of output used, the way that stochastic trends in the data are handled, and outliers in the monetary shock measure. When all three of these specifications are considered simultaneously, I find that monetary policy is more effective in recessions.

*Department of Economics, University of Oregon, (tstockwe@uoregon.edu)

1 Introduction

There is substantial interest in whether the effects of monetary policy are symmetric across multiple dimensions. The literature has focused on three manifestations of asymmetry: asymmetry related to the direction of the shock, asymmetry related to the size of the shock, and asymmetry related to the phase of the business cycle. The asymmetry literature began with Cover (1992) who was interested in directional asymmetry. Since then, a large literature has explored all three types of asymmetry with varying results. This paper will contribute to the business cycle asymmetry literature by attempting to reconcile these varying results. While this literature has focused on many countries including the United States, I study asymmetry using US data.

Most papers, such as Thoma (1994), Peersman and Smets (2002), Kaufmann (2002), Garcia and Schaller (2002), and Lo and Piger (2005) find that monetary policy has a larger impact on output during recessions than expansions. However, more recent evidence from Tenreyro and Thwaites (2016) finds that the output effects of monetary policy shocks are much larger in expansions than recessions. This paper has been influential and has left the literature with a lack of consensus. Reaching a consensus in this literature is important given the reliance of many nations on monetary policy to control inflation and output. If traditional monetary policy is not very effective at impacting output during recessions then fiscal policy and non-traditional monetary policy might have more of a place moving forward. The goal of this paper is to address why the literature comes to different conclusions about monetary policy and the business cycle.

Many of the papers in the business cycle asymmetry literature use a regime switching framework. This paper will follow this methodology by allowing effects of monetary policy on output to switch between expansions and recessions. I use monetary policy shock constructed as in Romer and Romer (2004) as the measure of monetary policy. Impulse response functions are generated using the method of local projections, developed in Jordá (2005). This approach allows for ease in the generation of impulse responses in non-linear models.

My analysis finds that there are three main reasons for the discrepancies in the asymmetry literature. First, outliers have a major impact on the impulse response functions. This finding is consistent with other papers in the asymmetry literature that have pointed out the influential impact of outliers. For example, Ravn and Sola (2004) found that the asymmetry results of Cover (1992) were not robust to a large outlier in the first quarter of 1983 in the money supply equation. Thoma (1994) found that the money-income relationship was stronger over periods where real output declines, being the strongest over the periods 1969-1973 and 1978-1982. Both cases feature data points during the Volcker chairmanship of the Federal Reserve. I also find that the early years of the Volcker chairmanship are very influential in generating business cycle asymmetry in the effects of monetary policy. Specifically, measured monetary policy shocks, including the Romer and Romer (2004) shocks used in this paper, display large outliers during the 1979-1982 period. When these outliers are controlled for, monetary policy flips from being more effective in expansions to being more effective in recessions.

Second, data frequency and the measure of output has an impact on the results. Papers in the asymmetry literature favor quarterly measures of output such as GDP, although there are papers that utilize monthly measures such as industrial production as their output measure. I find that while monetary policy was more effective in expansions in the quarterly real GDP specification, when monthly industrial production is used the effects in expansions versus recessions are approximately the same. This could be due to the higher sensitivity of industrial production to interest rate changes or the differences in how recessions are defined on quarterly and monthly frameworks. Either way, asymmetry results are impacted by the frequency of data chosen.

Finally, the way that trends are modeled when specifying the local projection regression is important. Most early papers in the asymmetry literature assume a stochastic trend and use models estimating the growth rate of the response variable. More recent papers, especially those using the local projections framework for estimating impulse responses (see Tenreyro and Thwaites (2016) and Ramey and Zubairy (2018)) run variables in log level form with a deterministic trend added to the equation. I explore the results using both the log level with trend specification and growth rate specification. I find that while the expansion effect was greater than the recession effect in the log level with trend specification, this disappears when output is expressed as growth rates.

The rest of the analysis proceeds as follows: section 2 lays out the existing literature on the subject and my contribution to this literature. Section 3 lays out the model to be estimated. Section 4 lays out the results of the analysis. Section 5 concludes.

2 Literature Review

Monetary policy asymmetry is the idea that monetary policy may have different effects on output or prices depending on what phase of the business cycle of the economy, the size of the monetary shock, or the direction of the monetary shock. This question is important for central banks, who should be interested if policies they take during recessions can increase output or control inflation during expansions. There is a sizable literature investigating the topic of monetary policy asymmetry, with most of these papers investigating a single type of asymmetry. This paper will focus on the asymmetry of policy effects relating to the phase of the business cycle. However, the remainder of this literature review will summarize the existing literature on all three types of asymmetry.

Business cycle asymmetry can be explained by three main theories. First, models with price rigidities, specifically prices that are more rigid downward than upward can generate asymmetry relating to the direction of the shock. This manifests itself as a convex short-run aggregate supply curve. Positive shocks to aggregate demand will have more of an affect on prices and less on output than a negative shock. This convex supply curve argument can also be used to explain business cycle asymmetry; the same shock to an equilibrium left of the long-run aggregate supply curve (a recession) would have a much different effect on output and prices than an equilibrium to the right of long-run aggregate supply. This model predicts that monetary policy would be more effective on output in recessions than expansions. Second, menu cost models can be used to explain asymmetry regarding the size of the shock. This model predicts that only small shocks will have large effects, since firms would only find it optimal to pay the menu costs if the shock was large enough. Finally, there is the credit channel explanation explored by Bernanke and Gertler (1995) that can explain asymmetry in different phases of the business cycle. This explanation runs through the balance sheet channel and finds that monetary policy is more powerful during recessions than expansions since firms are more likely to use internal financing during expansions but rely on external financing during recessions when internal funds dry up.

There have been many empirical investigations into asymmetry. The earliest paper in this field was Cover (1992). This paper employed a two step procedure to estimate the monetary shocks. First specify the money supply process and then obtain the residuals from the regression of that process. Second, these residuals are used as the monetary shock series upon which output can be regressed. He studied the difference between positive and negative monetary shocks, measured by shocks to the money supply. By regressing output growth on positive and negative money supply shocks, he found that positive shocks to money had no effect on output, but negative shocks decreased output. In addition to this paper, there were a few others that studied the asymmetry of positive versus negative shocks. Kandil (1995) and Karras (1996) found similar results to Cover (1992) while employing a similar method. Karras (1996) looked at a panel of 38 different countries and found evidence supporting international asymmetry. Kandil (1995) found that prices and wages tend to respond more to positive monetary shocks than negative ones. A more recent paper, Angrist et al. (2018) used propensity score matching on the policy variable and found that monetary tightening had an effect on yield curves and macroeconomic variables but monetary accommodation had less profound effects.

Many papers use a regime-switching framework to study asymmetry, allowing the models to differentiate between different phases of the business cycle or different types of shocks. Peersman and Smets (2002) allow for regime switching between high and low growth rate periods. They measure monetary policy as a shock to the short-term interest rate from a simple VAR model, finding that monetary policy in the Euro-area had significantly larger effects on output in recessions than expansions. Garcia and Schaller (2002) model regime switching as the economy switching from expansion and recession states. They use movements in the Federal Funds rate and innovations from a VAR as their monetary policy measures and find that US monetary policy has larger effects on output during recessions than expansions. Kaufmann (2002) allows for switching between above average and below average growth periods. Kaufmann uses the first difference of the Austrian 3-month interest rate as the policy variable and finds a significant negative effect of monetary policy on output during below average growth periods and insignificant effects during normal and above average growth periods.

Lo and Piger (2005) and Ravn and Sola (2004) also employ a regime switching framework and both papers study multiple manifestations of asymmetry in the same model. Ravn and Sola (2004) tie the regime switching to the mean and variance of the monetary shock, allowing them to study large versus small shocks in addition to positive and negative ones. Using US data, they find that large shocks are neutral while smaller shocks have real effects on output and less support of asymmetry between positive and negative shocks. Lo and Piger (2005) use this framework to study all three types of asymmetry. They use a time-varying transition probability model that allowed the switching process to be a function of the sign and size of the shock, as well as the phase of the business cycle. The shocks were identified from a monetary VAR model. Using US data, they found that policy actions taken during a recession had larger effects on output than actions taken during expansions, but less evidence of the other two types of asymmetry.

Weise (1999) is another paper that considers all three types of asymmetry at once. Money based indicators of monetary policy are used, which come from ordering money last in a VAR model. The innovation of this paper was to show that these asymmetries could be modeled by applying a smooth-transition technique (see Anderson and Teräsvirta (1992)), to a VAR model. Weise did not find evidence of asymmetry regarding the direction of the shock but did regarding the phase of the business cycle and the size of the shock. Shocks during low growth periods were found to have larger effects on output than shocks during high growth periods and large shocks were found to have disproportionately larger effect than smaller shocks.

The smooth-transition technique was also a highlight of Tenreyro and Thwaites (2016), following Granger and Teräsvirta (1993). This was also the paper that had the most influence on the methodology of this paper. They were interested in asymmetry dealing with the phase of the business cycle. Tenreyro and Thwaites (2016) innovated in two dimensions over the existing literature. First, they made use of the Romer and Romer monetary shocks from Romer and Romer (2004). Second, they employed local projections, developed in Jordá (2005), to generate impulse responses. Following these two methodologies they found that the response of output and prices to monetary policy shocks were more powerful in expansions than recessions.

The results of Tenreyro and Thwaites (2016) has been an influential and has left the business cycle asymmetry literature without a consensus. The primary objective of this paper is to reconcile the differences in this literature. As discussed above, there are differences in the way these various authors have identified monetary policy shocks and estimated the state-dependent response of the economy to these shocks. There are two additional key differences in this literature. The first is the measurement of the response variable, particularly the way that trends are removed from the data. The second is the treatment of outlier observations.

It is well known that how a researcher deals with stationarity is important for measuring the effects of policy innovations. One way this can be dealt with is by differencing the data and rendering it stationary. This is the strategy that most papers in the asymmetry literature deal with de-trending their data. Another strategy for de-trending the data is to add a time trend into the regression model. Papers in the more recent literature such as Tenreyro and Thwaites (2016) use this approach. Their use of levels data stems from other papers that use the local projection methodology, as other papers employing local projections also use levels data. For example, Ramey and Zubairy (2018) use levels data with a quartic trend. Regressions in levels are consistent even if there is a unit root (Sims et al. (1990)). However, Kilian and Kim (2011) find that there is a significant bias in IRF estimates when the process is persistent. Thus, while regressions in levels may seem safe since they are agnostic about the integration properties of the data, may give severely biased estimates. As I show in my paper, the de-trending strategy that the researcher uses can have a major impact on the asymmetry results.

The asymmetry literature generally measures monetary policy by using residuals from a simple monetary VAR or by using the Romer and Romer residuals, as discussed in section 3.2. In both cases, there are outliers in the measured shocks that happen during the 1979-1982 time period, corresponding to the Volcker chairmanship at the Federal Reserve. There have been some papers in the asymmetry literature that have highlighted the importance of the Paul Volcker chairmanship period, which lasted from 1979-1987. Prior to and during his chairmanship was a period characterized by high inflation rates, making the Feds primary goal during this time to reign in inflation. Volcker also oversaw the transition of the Fed from targeting the money supply to the Federal Funds rate as its primary policy tool. This paper finds that the results of asymmetry vary depending on how the residuals in this period are treated, much like other papers in this literature.

Morgan (1993) showed that changes in the Federal funds rate showed some asymmetry in output when looked at over the full sample 1963:2-1992:3, finding that increases in the funds rate had more of an effect than a decrease. There is less evidence for this result when the period 1979:4-1982:4 was excluded from the sample, the period when the Fed deemphasized the Federal funds rate. Thoma (1994) studied asymmetry and instability in the money-income causality. He used a rolling regression approach to show that the p-value of the money-income causality test is highly correlated with the level of real economic activity. There were two periods in his sample that this relationship was the strongest, 1969-1973 and 1978-1982. Ravn and Sola (2004) were also concerned about this period, their regime switching model allowing them to control for the Volcker period since the change in policy that happened then produced some large negative outliers that needed to be controlled for. Specifically they found that a large outlier in the money supply equation appeared in the first quarter of 1983. They found that the results of Cover (1992) were not robust to this outlier. Even Romer and Romer (2004) find outliers during this time period and find that there are many problems with measuring shocks during this time. The baseline specification in this paper follows Romer and Romer (2004) by generating residuals from an estimation of the Feds reaction function. Analyzing the data for this period, one will find that the residuals generated will typically be the largest during the 1979-1982 period, suggesting that some of the varying results observed in the asymmetry literature might be driven by how papers dealt with this time period. The results are similar to Ravn and Sola (2004) in that asymmetry disappears when I control for this time period.

3 Econometric Method

In this section, I lay out the econometric method used in the paper. This section begins with a discussion of the local projection methodology for computing impulse responses and how inference is conducted in this framework. Second, the Romer and Romer (2004) monetary policy shock measure is discussed. Third, a brief description of the data used for this paper is discussed. Finally, this section concludes with a discussion of how asymmetry is tested for in this paper.

3.1 Local Projections

I follow Tenreyro and Thwaites (2016) in the use of the local projection model for estimating impulse responses, developed in Jordá (2005). The local projection approach has a few advantages over a VAR model. First, it is simple to estimate and draw inference from, requiring only running OLS over increasing time horizons. Second, this model is robust to misspecification of the data generating process. Finally, it can more easily accommodate non-linear specifications in multivariate contexts. For the purpose of studying business cycle asymmetry in the response of output to monetary policy, local projections proceeds by estimating equations of the form:

$$y_{t+h} = F_t(\beta_r^h \varepsilon_t + \gamma_r' x_t) + (1 - F_t)(\beta_e^h \varepsilon_t + \gamma_e' x_t) + u_t \tag{1}$$

where y_{t+h} is output measured in log levels at time horizon h, F_t is an indicator variable indicating if the US economy is in a recession or an expansion, ε_t is the monetary policy shock, and x_t is a control vector. The coefficients of interest are β_r^h indicating the response of output at horizon h to monetary policy shocks in recessions, and β_e^h being the response at horizon h during expansions.

Equation 1 is estimated using log levels of the output variable. One might be interested in instead working with first differences of the logged output variable, such as in the case where the log level of output is thought to have a unit root. To do so, consider first the local projection of the first difference of the log level of output on the monetary policy shock:

$$\Delta y_{t+h} = F_t(\beta_{r,D}^h \varepsilon_t + \gamma_r' x_t) + (1 - F_t)(\beta_{e,D}^h \varepsilon_t + \gamma_e' x_t) + u_{t+h}^D$$

where $\beta_{r,D}^h$ and $\beta_{e,D}^h$ are the responses of the growth rate of output to a monetary shock in recessions and expansions respectively. Note that the sum of growth rate responses gives the level responses. We can estimate this level response directly in the growth rate specification using the transformation suggested in Stock and Waton (2018). Summing the growth rates over h gives:

$$\sum_{i=0}^{h} \Delta y_{t+i} = F_t(\sum_{i=0}^{h} \beta^i_{r,D}\varepsilon_t + \gamma_r' x_t) + (1 - F_t)(\sum_{i=0}^{h} \beta^i_{e,D}\varepsilon_t + \gamma_e' x_t) + \sum_{i=0}^{h} u^D_{t+i}.$$

This can be simplified:

$$\sum_{i=0}^{h} \Delta y_{t+i} = F_t(\beta^h_r \varepsilon_t + \gamma_r' x_t) + (1 - F_t)(\beta^h_e \varepsilon_t + \gamma_e' x_t) + \sum_{i=0}^{h} u^D_{t+i}$$

where β^h_r and β^h_e are the responses of the log level of output to a monetary shock in recessions and expansions respectively. These responses, β^h_r and β^h_e, are equal to the sum of the growth rate responses up to horizon h, $\sum_{i=0}^{h} \beta^i_{r,D}$ and $\sum_{i=0}^{h} \beta^i_{e,D}$. The terms inside the summation $\sum_{i=0}^{h} \Delta y_{t+h}$ cancel out, until this equation is left:

$$y_{t+h} - y_{t-1} = F_t(\beta^h_r \varepsilon_t + \gamma_r' x_t) + (1 - F_t)(\beta^h_e \varepsilon_t + \gamma_e' x_t) + \sum_{i=0}^{h} u^D_{t+i}. \quad (2)$$

The impulse response for the logged first difference of output in recessions is β^h_r and β^h_e in expansions. The standard errors are calculated from the estimation of equation 2. This specification will be helpful because it will allow us to directly compare the impulse responses from the log level form of output to the logged first difference form.

Following Tenreyro and Thwaites (2016), the control vector will contain one lag each of output and the Federal funds rate. Impulse responses will be calculated out to twenty quarters, $H = 20$ (or 60 months in the monthly specification). The shocks developed in Romer and Romer (2004) will be used as the measure of the monetary policy shock (see section 3.2) and real GDP will be the main dependent variable. I run specifications in both levels and growth rates. A linear time trend is added to any model estimated in level form.

The NBER indicator, that will be used as F_t in equation 1, is a monthly variable published by the National Bureau of Economic Research indicating if the US economy is in a recession or expansion. To convert this monthly measure to a quarterly measure I count a quarter as in recession when at least two of the three months in that quarter are counted as a recession by the monthly NBER indicator. This indicator is denoted the NBER majority rule indicator. The use of this indicator is in contrast to other papers which use a logistic function in the regime switching framework. Granger and Teräsvirta (1993) and more recently Tenreyro and Thwaites (2016) both use a logistic function in their smooth transition models. I prefer the NBER specification as it offers a more clear definition about which quarter is in a recession state versus an expansion state.[1]

I employ the Newey-West methodology to calculate asymptotic standard errors. As Jordá (2005) shows, the disturbance term in the local projection equation is serially correlated and has a moving average (MA) process. I use these standard errors to calculate 90% confidence intervals around the impulse response of output in recessions and expansions from Equations 1 and 2 depending on the specification of output. The maximum autocorrelation lag is set to be H+1 following Jordá (2005).

3.2 Non-Linear Romer and Romer (2004) Monetary Policy Shocks

I make use of the monetary policy shocks developed in Romer and Romer (2004). One must be mindful of the endogenous or anticipatory movements that plague monetary policy measures such as the money supply or the Federal funds rate. Romer and Romer (2004) developed a two-step process to derive a measure of monetary policy that is free from these problems. First, the intended Federal Funds rate for a given Federal Open Market Committee (FOMC) meeting is found by reading the narrative record of each FOMC meeting. Second, the intended funds rate series is regressed around the forecast dates of the Fed's Greenbook forecasts. The Greenbook forecast is produced prior to each FOMC meeting by the research staff of the Board of Governors. The forecasts contain projections of many macroeconomic variables of output, prices, employment, and investment. By regressing the intended funds rate on these forecasts, the residuals from this regression are now free of anticipatory movements. These residuals are the series of interest.

[1]The results of this paper are robust to the smooth transition model.

I follow Tenreyro and Thwaites (2016) in the use of non-linear Romer and Romer (2004) shocks. Given that the premise of this study is to estimate non-linearities in the response of monetary policy, subjecting the reaction function of the Federal Reserve to be linear may add some state dependent measurement error, causing asymmetry to show up where there is none. The original Romer and Romer (2004) regression is written as follows:

$$\begin{aligned}\Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \widetilde{\Delta y}_{m,i} + \sum_{i=-1}^{2} \lambda_i (\widetilde{\Delta y}_{m,i} - \widetilde{\Delta y}_{m-1,i}) \\ + \sum_{i=-1}^{2} \phi_i \widetilde{\pi}_{m,i} + \sum_{i=-1}^{2} \theta_i (\widetilde{\pi}_{m,i} - \widetilde{\pi}_{m-1,i}) + \rho \widetilde{u}_{m,0} + \varepsilon_m\end{aligned}$$

where Δff_m is the change in the intended funds rate around FOMC meeting m, ffb_m is the level of the intended funds rate before any changes were made at the associated FOMC meeting, $\widetilde{\Delta y}$ is the forecast of real output growth, $\widetilde{\pi}$ is the forecast of inflation, and $\widetilde{u}$ is the forecast of the unemployment rate. Define X_m as:

$$\begin{aligned}X_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \widetilde{\Delta y}_{m,i} + \sum_{i=-1}^{2} \lambda_i (\widetilde{\Delta y}_{m,i} - \widetilde{\Delta y}_{m-1,i}) \\ + \sum_{i=-1}^{2} \phi_i \widetilde{\pi}_{m,i} + \sum_{i=-1}^{2} \theta_i (\widetilde{\pi}_{m,i} - \widetilde{\pi}_{m-1,i}) + \rho \widetilde{u}_{m,0}\end{aligned}$$

then we can express the original Romer and Romer (2004) regression as follows:

$$\Delta ff_m = \beta' X_m + \varepsilon_m$$

where X contains the control variables from the Greenbook forecasts and the residuals ε_m are the linearly identified monetary policy shocks. The state-dependent reaction function is then:

$$\Delta ff_m = NBER * \beta' X_m + (1 - NBER) * \beta' X_m + \varepsilon_{m,nl} \tag{3}$$

where NBER is an indicator variable for recession or expansion. In this framework $\varepsilon_{m,nl}$ represents the non-linear monetary policy shocks.

3.3 Data

The data used in this study was taken from a variety of sources. Real GDP, industrial production, personal consumption expenditure, and federal funds rate data was taken from the St. Louis Federal Reserve's FRED database. The NBER indicator data was taken from the National Bureau of Economic Research recession indicators. Finally, the data used to generate the Romer and Romer (2004) monetary policy shocks was collected from the Philadelphia Federal Reserve's Greenbook data set. The main sample period for the quarterly frequency runs from 1969:Q1-2008:Q4. Since H=20, the last 20 quarters of this sample are reserved for the calculation of impulse responses by local projections. For monthly, the sample period runs from 1969:03-2008:12. For consistency with the quarterly analysis, the last 5 years of this sample will be reserved for impulse response calculation by local projections. In both cases the sample period cuts off prior to the onset of the Great Recession, since the interest rate was near the zero lower bound for most of the duration and aftermath of the recession.

3.4 Asymmetry Test

To test for asymmetry, Equation 1 is rewritten as follows:

$$y_{t+h} = \beta_r^h \varepsilon_t + \gamma_r' x_t + (1 - F_t) * (\theta_e^h \varepsilon_t + \gamma_e' x_t) + u_t. \tag{4}$$

In this specification, the coefficient θ_e^h has the interpretation of being the response of output in expansions minus the response of output during recessions. Similarly for growth rate specifications, Equation 2 can be rewritten as follows:

$$y_{t+h} - y_{t-1} = \beta_r^h \varepsilon_t + \gamma_r' x_t + (1 - F_t)(\theta_e^h \varepsilon_t + \gamma_e' x_t) + \sum_{i=0}^{h} u_{t+h}^D. \tag{5}$$

where θ_e^h has the same interpretation as in Equation 4. The standard error for θ_e^h is calculated using the Newey-West methodology and a t-test is performed on the coefficient θ_e^h. There is evidence for asymmetry if the corresponding p-value is low enough to reject the null hypothesis of no asymmetry at the 10% significance level.

4 Results

In this section, I present the results of the estimation of the model laid out in section 3. I then consider various variants of this model in an attempt to reconcile the differences in the existing literature.

4.1 Baseline Results

I begin with the baseline specification that mirrors the specification Tenreyro and Thwaites (2016) used in their analysis. In Tenreyro and Thwaites (2016) they ran a local projection model using a smooth-transition logistic function to switch between expansion and recession regimes. They found a significant difference between the impulse responses of output between expansions and recessions. The impulse response of output in expansions reached its peak about ten periods from the time of the shock while the recession response stayed closer to zero for the duration of the horizon. They conducted inference using both a bootstrap method and asymptotic standard errors. The results from the asymptotic standard errors showed a significant difference between the response of output in expansions and recessions to a monetary shock while the bootstrap test was inconclusive.

Figure 1 shows the impulse response of real GDP to a positive Romer and Romer (2004) monetary shock and shows the results of the asymmetry test for this variable. These results very closely mirror the Tenreyro and Thwaites (2016) result. The impulse responses are generated using Equation 1. In Figure 1a-1c, red lines indicate the response of output in a recession and blue lines show the response in an expansion. Variables in the equation are in log levels and a linear time trend is included in the model. The key interest in Figure 1a is the difference between the two impulse response lines. Aside from a brief period at the beginning of the horizon, the expansion line is lower than the recession line for the remainder of the horizon, reaching its peak difference around ten quarters from the time of the shock. For most of the duration of the horizon, the recession response stays close to zero.

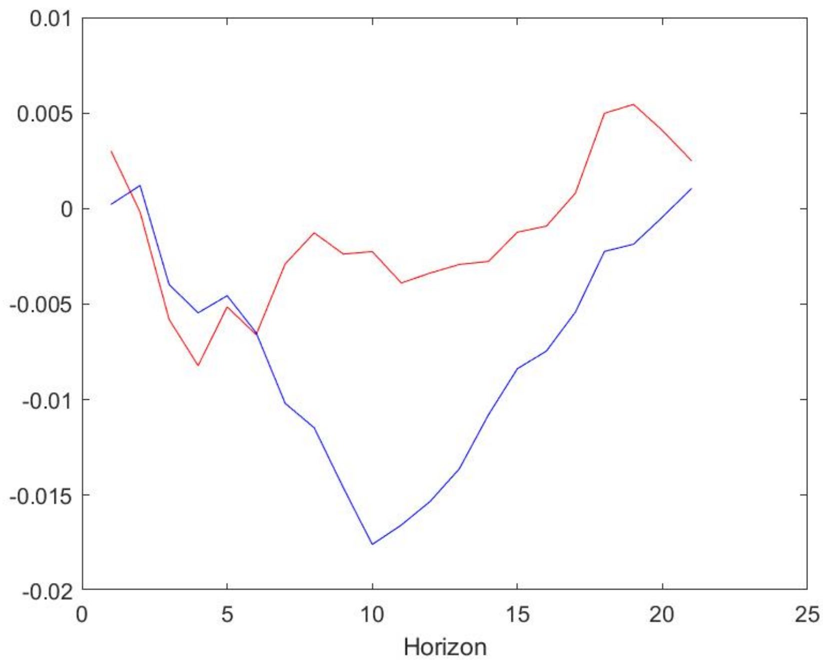
Figures 1b and 1c give us evidence that the responses in expansions and recessions are both significantly different from zero. The expansion response of output is significant from zero from approximately horizon 7-18, and its peak response is -0.017. The recession response of output is only significantly different from zero in the early part of the horizon and its peak response is approximately -0.007. The point estimates suggest that asymmetry exists between the response of output in expansions and recessions.

To confirm that these differences are significant from each other, a t-test is performed on the sign of $\beta_e^h - \beta_r^h$ following Equation 4. Figure 1d shows the p-value of the t-test using Newey-West standard errors. Referencing back to Figure 1a, the largest differences happen between horizons 9-15, corresponding to the horizons that the t-test find a significant difference. Given the evidence from the point estimates and the t-test, Figure 1 largely mirrors the findings of Tenreyro and Thwaites (2016) that the response of output to a monetary shock in expansions is larger than during recessions. The remainder of this section will explore how robust this result is to different specifications of the model.

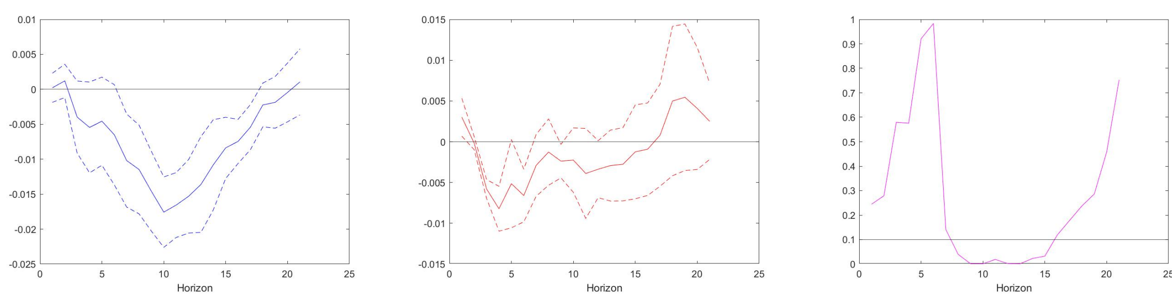
4.2 Robustness to Measure of Output and Data Frequency

Many papers in the asymmetry literature have used Industrial Production as the measure of output. Weise (1999), Peersman and Smets (2002), Garcia and Schaller (2002), and Lo and Piger (2005) all used industrial production in their baseline specifications. Romer and

Figure 1
Impulse Response Function of Quarterly real GDP using the Levels Specification



(a) Point Estimates



(b) Expansion **(c) Recession** **(d) t-test p-value**

Notes: This Figure shows the impulse response of real GDP in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in log levels and a linear time trend is added to the model. The sample is quarterly from 1969:Q1-2008:Q4. Figure (a) shows the impulse response point estimates for expansions and recessions. Figure (b) and (c) show the impulse responses with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the response in expansions and recessions with the line in the figure corresponding to the 90% significance level.

Romer (2004) also used industrial production to evaluate their monetary shock measure. Kaufmann (2002), Ravn and Sola (2004), and Tenreyro and Thwaites (2016) use measures of GDP as their measures of output. Industrial production is a narrower measure of output than GDP that is also more sensitive to interest rates. This section explores the robustness of the results in section 4.1 to the measure of output.

Figure 2 shows the impulse response of quarterly industrial production to a monetary shock in expansions and recessions. The model is run in log levels with a linear time trend added to the model. The expansion response tells a similar story to the response in Figure 1. The main difference between Figure 2a and Figure 1a is the peak response of industrial production in expansions and recessions. In expansions, the peak response is between -0.02 and -0.025 using industrial production compared to -0.017 in the baseline case, showing more sensitivity to interest rates than the baseline case. The recession response to a monetary shock also shows more sensitivity as the peak response in Figure 1 was -0.007 versus -0.017 when industrial production is used. The recession response of industrial production also stays around -0.010 from horizon 8-17 before it heads back up to zero. This is in contrast to Figure 1a, where the response went right back to zero after reaching its peak.

Figures 2b and 2c allow us to identify if the point estimates from Figure 2a are significantly different from zero at the 10% level. A comparison of the expansion responses for real GDP and industrial production is very similar in terms of significance. Around horizon 10, which corresponds to the peak point estimate in absolute value, the impulse response for expansion shows a significant difference from zero. The response during recessions has two periods of significance. The first occurs around horizon 6, corresponding to the peak response in absolute value, and the other from horizon 12-16.

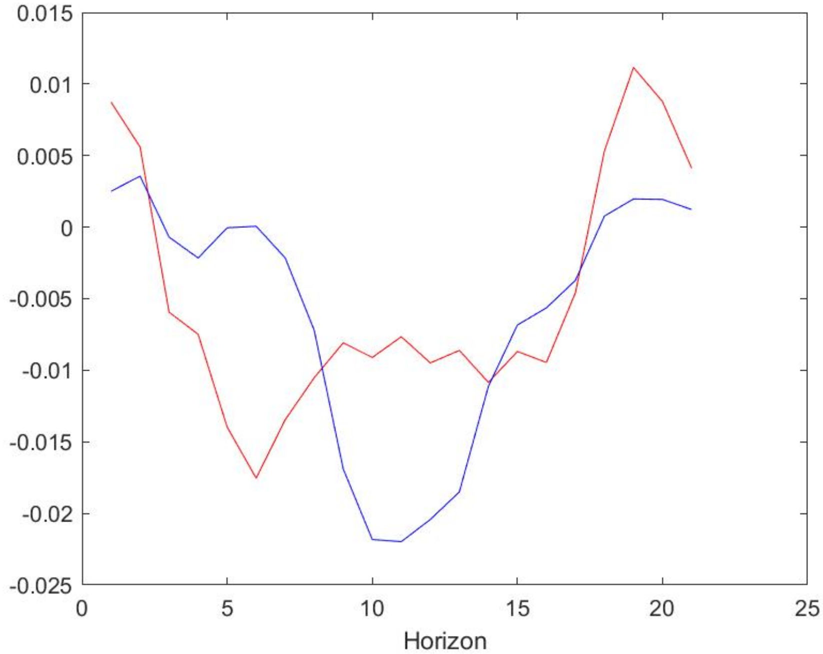
The evidence thus far suggests that when industrial production is used in place of real GDP, that the recession response closes the gap but still does not pass the response in expansions. However, the results of the t-test for asymmetry gives inconclusive results. The t-test says that there is a significant difference between expansions and recessions at horizon zero but this difference is not useful for asymmetry. At all other horizons, the t-test does not find any significant differences.

The results for industrial production are less clear that that of real GDP. The peak response for expansions is still larger than it is during recessions although there were no significant differences found from the asymmetry tests. Given that there is weak evidence that industrial production is more responsive to a monetary shock in expansions, changing the measure of output does not overturn the results from section 4.1.

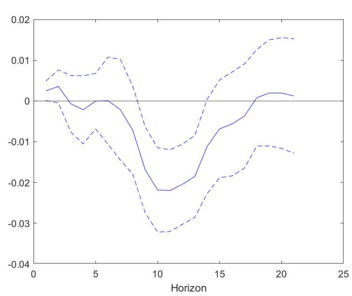
In addition to variability in the measure of output used, there has also been some variability in the data frequency used in the asymmetry literature. Most papers tend to favor quarterly measures since GDP is measured in quarterly frequency. Given the nature of quarterly measures, there may be some difficultly defining recessions in this time frequency. For example, the quarterly NBER indicator that I use requires that two of the three months in a quarter be in a recession in order for that quarter to be counted as a recession. There are certain quarters where only one month was in a recession but this would not be counted as such in the NBER definition used. This happens in 1973:Q4, since only December of 1973 was counted as a recession by the NBER. As higher frequency data specifications are used, recessions become more clearly defined since this lowers the chance that one period of time can be counted as a recession in the monthly measure but an expansion in the quarterly measure. In this section, I explore how robust the baseline result is to the frequency of the data.

Figure 3 shows the impulse response of Industrial Production to a positive monetary policy shock. There are two main differences between the regression used to obtain these results and the baseline quarterly results. First, the Romer and Romer shocks are measured monthly rather than quarterly. Romer and Romer (2004) construct monthly shocks originally and then aggregate these to quarterly, so there is no measurement problem here. Second, the measure of output is industrial production versus real GDP in the baseline quarterly case. The impulse response runs out to time 60, which is five years and consistent with the

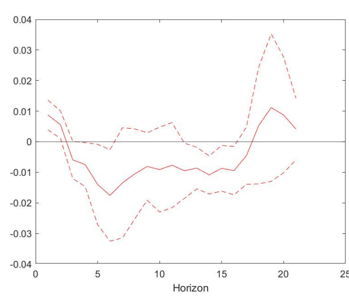
Figure 2
Impulse Response Function of Quarterly Industrial Production using the Levels Specification



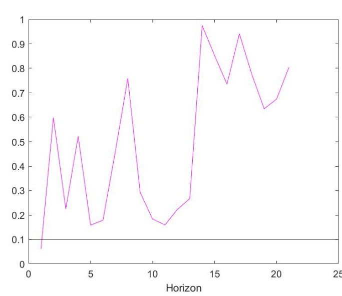
(a) Point Estimates



(b) Expansion



(c) Recession



(d) t-test p-value

Notes: This Figure shows the impulse response of Industrial Production in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in log levels and a linear time trend is added to the model. The sample is quarterly from 1969:Q1-2008:Q4. Figure (a) shows the impulse response point estimates for expansions and recessions. Figure (b) and (c) show the impulse responses with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the response in expansions and recessions with the line in the figure corresponding to the 90% significance level.

quarterly case.

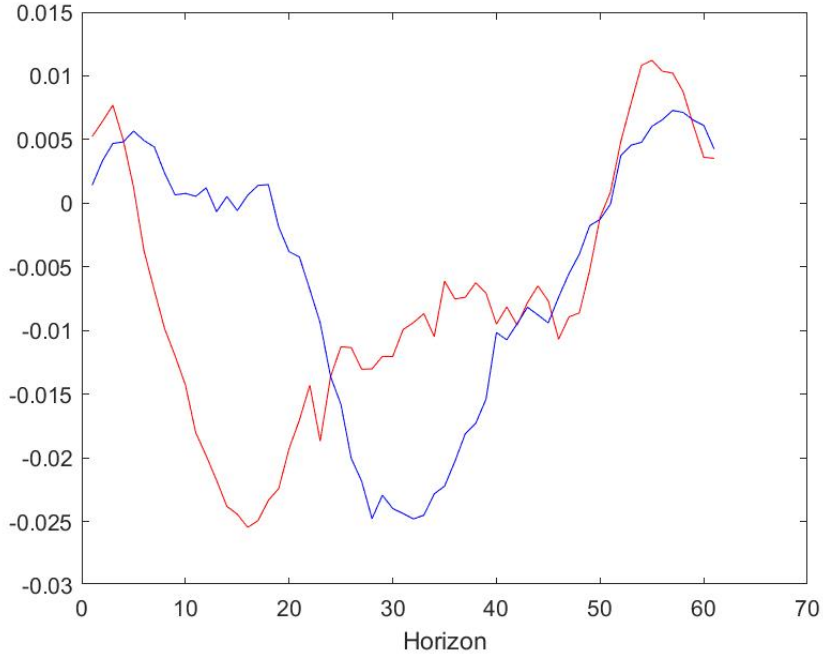
Figure 3 shows that the results are similar to Figure 2. Comparing Figure 3a to Figure 2a, there is still a timing difference visible between the response in expansions and recessions. The difference is that the peak recession response has now increased to the point of surpassing the peak expansion response. Therefore, while the baseline results were weakened by the use of quarterly industrial production, this weakness is accentuated by switching from quarterly to monthly industrial production. It is important to note that when monthly industrial production is used that there are horizons where both camps of the literature are correct. From horizons 5-25 the recession response is stronger and from 25-40 the expansion effect is stronger.

The confidence interval around the point estimate for the expansion response is consistent with the impulse responses of quarterly real GDP and industrial production. For the periods around horizon 30, the peak expansion response, there are significant differences from zero. Switching to monthly now has the recession response exhibiting similar behavior to the expansion response. It is significantly different from zero in many places along the horizon, including horizon 5-20 (which contains the peak response in recessions) and intermittent intervals over the rest of the horizon.

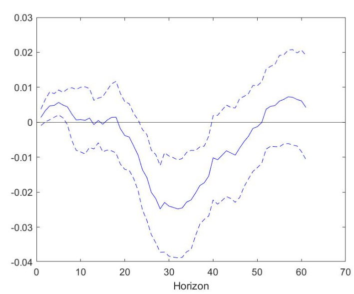
The asymmetry test for monthly industrial production is in Figure 3d. There are two places that exhibit significant differences in the responses between expansions and recessions. The recession response is significantly larger between horizons 6-9 and around horizon 15. The expansion response is significantly larger around horizon 33.

Given the results in Figure 3, the frequency of the data used can have a major effect on asymmetry results. As stated above, this result is likely due to recessions being defined more clearly in the monthly specification rather than quarterly. Given the results of this section, it appears that the measure of output used has a major impact on the asymmetry results, with the frequency of data used accentuating this result.

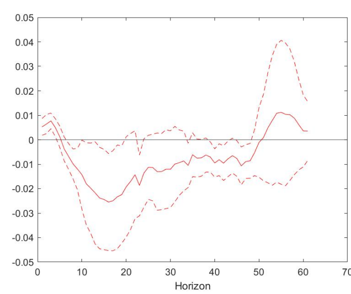
Figure 3
Impulse Response Function of Monthly Industrial Production using the Levels Specification



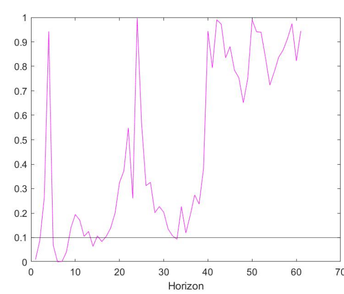
(a) Point Estimates



(b) Expansion



(c) Recession



(d) t-test p-value

Notes: This Figure shows the impulse response of Industrial Production in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in log levels and a linear time trend is added to the model. The sample is monthly from 1969:03-2008:12. Figure (a) shows the impulse response point estimates for expansions and recessions. Figure (b) and (c) show the impulse responses with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the response in expansions and recessions with the line in the figure corresponding to the 90% significance level.

4.3 Robustness to Treatment of Stochastic Trends

There is some variability in the asymmetry literature with the way that trends in the data are dealt with. Most early papers in the literature assume a unit root in output and specify their empirical models in terms of the growth rates of output measures. More recent papers, especially those using local projections for impulse responses, use the level of the data augmented with a time trend to the model. In this section, I demonstrate that the asymmetry results are not robust to the choice of estimating the model in levels versus growth rates.

Figure 4 shows the impulse response of real GDP growth to a monetary shock. The impulse responses for the growth rate specification are generated from estimating Equation 2. Figure 4a shows the cumulative sum of the growth rate response making it comparable to the log level responses from the previous sections. Figure 4b and Figure 4c shows the impulse responses for the cumulative sum of the growth rates in expansions and recessions and the t-test for asymmetry in Figure 4d tests for the differences between the cumulative sum of the growth rates in expansions and recessions.

Figure 1a suggested that output was more responsive to monetary policy in expansions than recessions. The point estimates in Figure 4a appear to wash out the result in the baseline specification. Here the peak response in expansions and recessions are about equal, -0.010 and -0.012 respectively. The response in the recession regime reaches its peak response more quickly and stays there for longer than the expansion regime. From horizons 1-9 and 11-20 the response of output in recessions is much lower than the response during expansions, suggesting that monetary policy is more effective in recessions than expansions. This result is in contrast to Tenreyro and Thwaites (2016) but in agreement with much of the rest of the asymmetry literature.

Figures 4b and 4c show the response of the cumulative sum of the growth rates of real GDP to a monetary shock. There are a couple of periods of interest in these two graphs. One, the recession response is significantly different from zero in the early part of the horizon, between horizons 3 and 6. The expansion response is significantly different from zero in the middle of the horizon, around horizon 9-12.

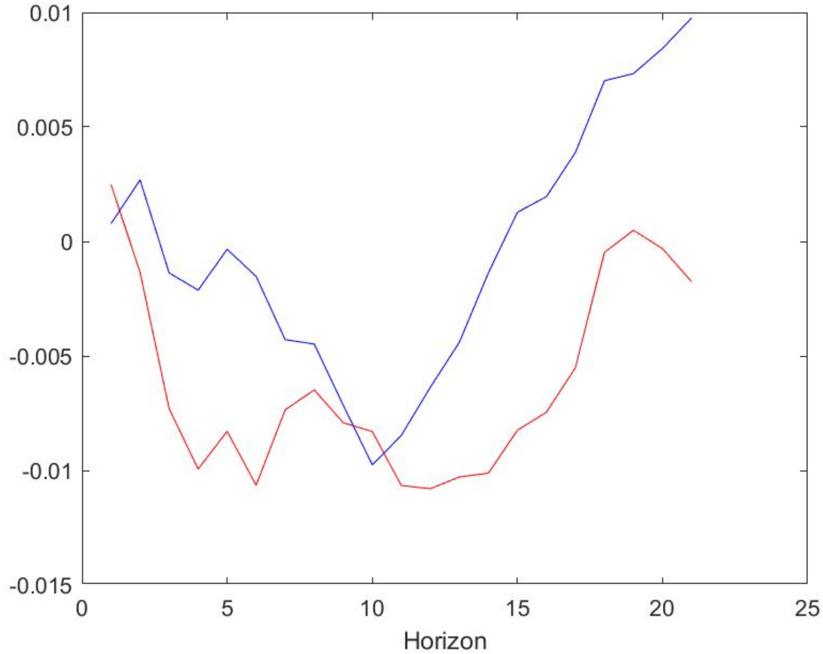
Figure 4d shows the p-values of the t-test for asymmetry between the cumulative sum of the growth rates between expansions and recessions. The p-value shows evidence that there is asymmetry between expansions and recessions, with the response in recessions being larger. During horizons 2-6 and 15-20, the response in recessions is larger than expansions. The t-test finds that these differences are significant. The only period that the t-test does not find a significant difference is between horizons 6-14, where the expansion response reaches its peak.

Given the results of Figure 4, there is weak evidence that monetary policy is more effective in recessions when real GDP is expressed in terms of growth rates. I have shown that the measure of output and the frequency of the output variable had an effect on the asymmetry results based on levels regressions. Figure 5 combines these results showing the impulse response of monthly industrial production growth to a positive monetary shock. This specification is identical to the one in Figure 4 with monthly industrial production growth replacing quarterly real GDP growth.

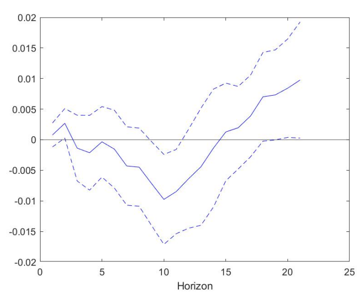
Comparing the point estimates in Figure 5 to the monthly specification in Figure 3 gives further evidence that the switch to growth rates flips the baseline result. In Figure 3 the story was one of timing. Expansions and recessions had approximately the same peak response but the peak happened earlier in recessions. In Figure 5, the response in recession still reaches its peak well before the response in expansions but it strictly dominates in terms of response size over the entire horizon. The recession response quickly reaches -0.025 and stays there while only reaching -0.015 for a brief period in the expansion response.

Figure 5b and Figure 5c show that there are a few periods where the cumulative response of the growth rate of industrial production are significantly different from zero. The recession response has some significance between horizons 6-18 and 45-50. The expansion response is only significantly different from zero in the early portion of the horizon. The remainder of

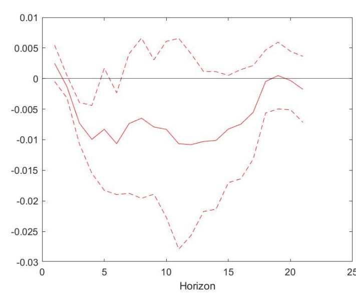
Figure 4
Impulse Response Function of Quarterly real GDP using the Growth Rate Specification



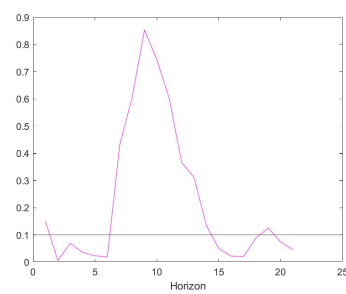
(a) Point Estimates



(b) Expansion



(c) Recession



(d) t-test p-value

Notes: This Figure shows the impulse response of real GDP growth in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in logged first difference. The sample is quarterly from 1969:Q1-2008:Q4. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of real GDP with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of real GDP in expansions and recessions with the line in the figure corresponding to the 90% significance level.

the horizon is insignificant, even where it reaches its peak response.

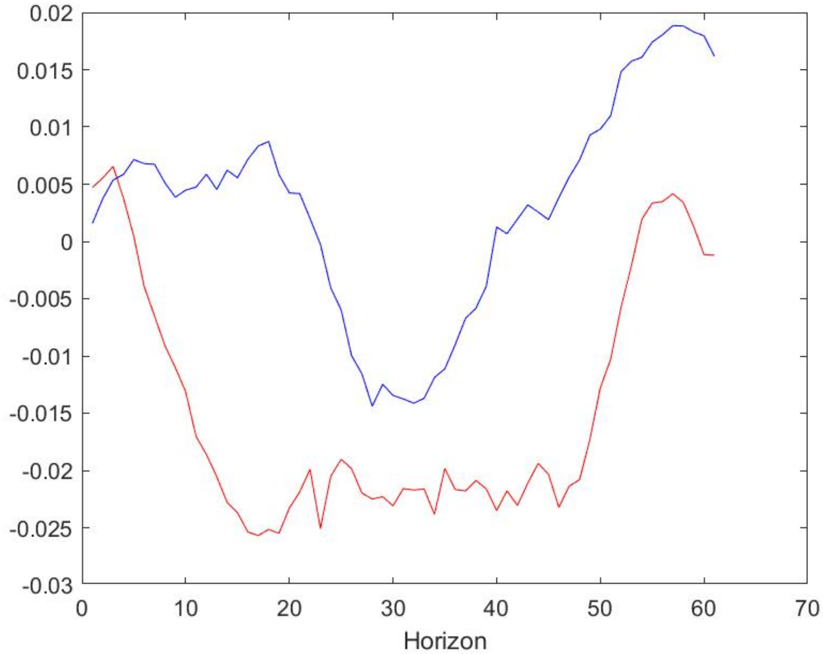
The results of the asymmetry test of the cumulative growth rates in Figure 5d is similar to the result of using quarterly real GDP growth. In the t-test you will find significant differences between the responses in expansions and recessions in the early portion of the horizon, between horizons 6-18. This period corresponds to the response in recessions reaching its peak rapidly while the expansion response stays close to zero. Even though there is no other horizon that shows evidence of asymmetry, this does give more evidence that monetary policy is more effective in expansions than recessions.

Given the results from Figures 4 and 5, there is evidence that estimating the model in levels versus growth rates has has a major impact on the asymmetry results. Which specification should be trusted? On the one hand, if there is no unit root, the differences specification over-differences the data, introducing a non-invertible moving average component into the regression disturbance. This danger of over-differencing for the purposes of impulse response estimation is discussed in Gospodinov et al. (2013) for IRF analysis using VARs. However, if there is a unit root, the differenced specification should be more efficient, and the levels specification, while consistent, will be severely biased in finite samples (Kilian and Kim (2011)). Also, typical inference methods employed in the literature using local projections, such as Newey-West standard errors, are not robust to the presence of a unit root.

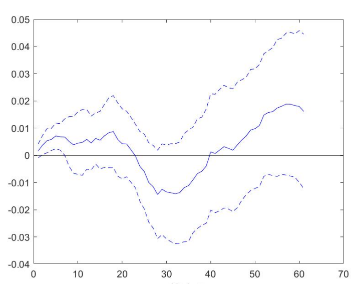
In an attempt to provide evidence on the correct specification, I run unit root test on the quarterly real GDP series from 1959:Q1-2018:Q2. The tests run include the augmented Dickey-Fuller test (ADF), the Elliot, Rothemberg, and Stock test (DF-GLS), the Zivot-Andrews test (ZA), and the KPSS stationarity test. The results of these tests are presented in Table 1.

The evidence from these tests points to there being a unit root present in the quarterly real GDP series. The ADF and DF-GLS tests both have a null hypothesis that the series has a unit root while the alternative is a trend stationary series. The tests statistics for these two tests are -2.2335 and -0.7539, neither being significant at any conventional level. The null

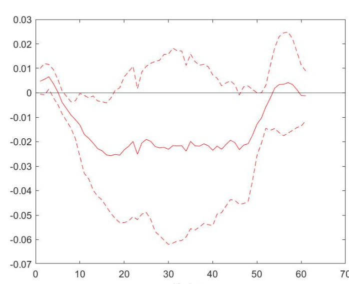
Figure 5
Impulse Response Function of Monthly Industrial Production using the Growth Rate Specification



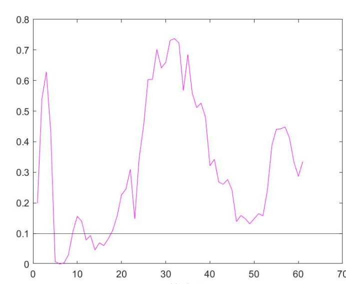
(a) Point Estimates



(b) Expansion



(c) Recession



(d) t-test p-value

Notes: This Figure shows the impulse response of industrial production growth in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in logged first difference. The sample is monthly from 1969:03-2008:12. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of industrial production with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of industrial production in expansions and recessions with the line in the figure corresponding to the 90% significance level.

hypothesis of the Zivot-Andrews test is that the series has a unit root while the alternative is a trend stationary series with a break at an unknown point in either the intercept, the linear trend, or in both. The test statistic is -4.4729 and I fail to reject the null at any conventional significance level. The final test is the KPSS test where the null is a trend stationary series and the alternative is that the series has a unit root. The test statistic for this test is 0.8888, which is significant at the 10% level.

The evidence from these tests does suggest that the real GDP series has a unit root. This result is supported by both unit root and stationarity tests, suggesting the result is not driven by a lack of power. In addition, this result was robust to shortening the sample period to 1959:Q1-2008:Q4 and to the use of monthly industrial production as the output measure. Given these results, it is not unreasonable to conclude that the results from the differences specifications are more credible.

Table 1
Unit Root Tests of Quarterly real GDP

Sample Period	ADF	DF-GLS	Zivot-Andrews	KPSS
1959:Q1-2018:Q3	-2.2335	-0.7539	-4.4729	0.8888*
1959:Q1-2008:Q4	-3.1341	-1.1755	-3.8401	0.3907*

Notes: The results of various unit root tests over the time horizons 1959:Q1-2018:Q3 and 1959:Q1-2008:Q4. A * indicates significance at the 10% level. The first test is an Augmented Dickey Fuller test where the null hypothesis is that the series has a unit root and the alternative is trend stationary. The second is an Elliot, Rothemberg, and Stock "DF-GLS" test where the null hypothesis is that the series has a unit root and the alternative is trend stationary. The third is a Zivot-Andrews test where the null hypothesis is that the series has a unit root and the alternative is trend stationary where the trend has a break in it. The fourth test is the KPSS stationarity test where the null is the series is trend stationary and the alternative is that the series has a unit root.

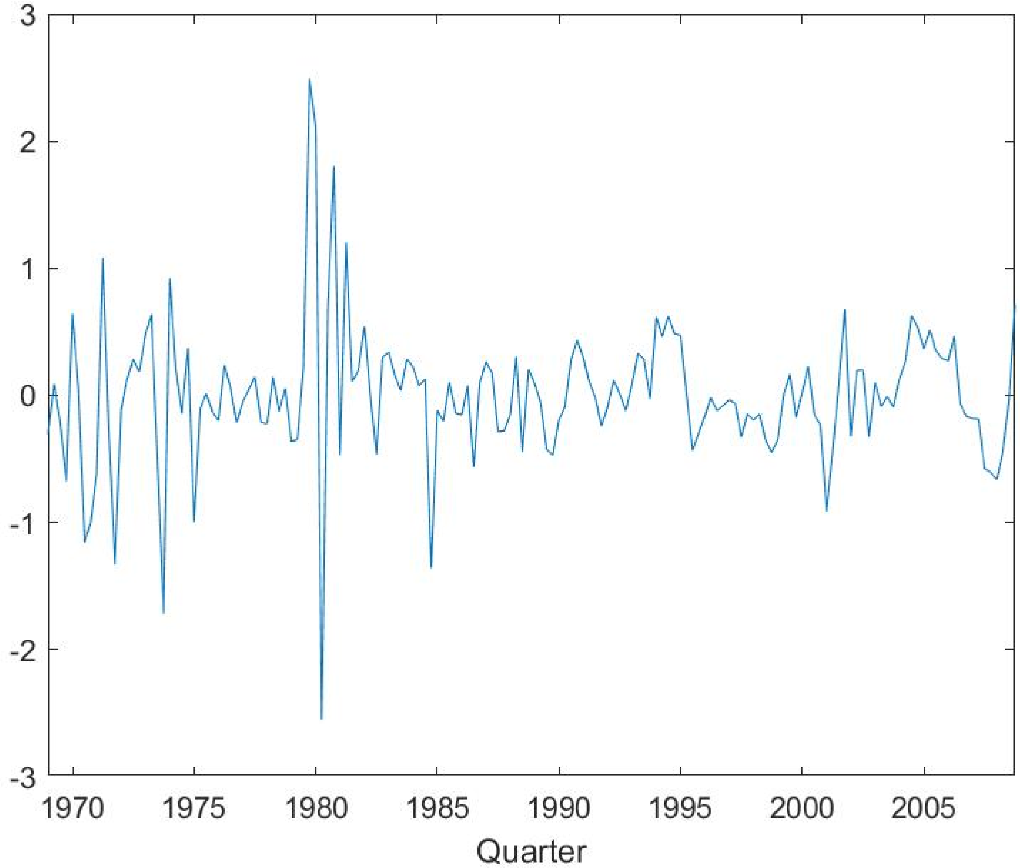
4.4 Robustness to Outliers

As was discussed in sections 1 and 2, the Volcker chairmanship of the Federal Reserve was a period of change in the conduct of monetary policy. There was significant emphasis placed on reducing the high inflation rates that persisted during the 70's and the Fed also switched from money supply to interest rate targeting. Many asymmetry papers have used measures of interest rates or money supply as their measure of monetary policy in the past. The Volcker period makes it unclear which one measure is the correct one to use given that the target switched during this time period. I use Romer and Romer (2004) monetary shocks to measure monetary policy which allows us to circumvent this measurement problem during the Volcker period. Romer and Romer (2004) discuss in their paper that even when the FOMC was not explicitly targeting the Federal Funds rate, they were concerned about this key interest rate and the implications that policy actions would have on the funds rate. Because of this it is natural to construct a shock series using the intended Federal Funds rate for the duration of the sample period.

That being said, there are still potential problems with using the Romer and Romer (2004) monetary shocks over this period as there are large outliers in these shocks during the Volcker period. A few of the papers in the asymmetry literature have explored how this period impacted the results of asymmetry such as Morgan (1993) and Thoma (1994). In this section, I demonstrate how the baseline results change depending on how the researcher deals with this period.

Figure 6 plots the updated non-linear Romer and Romer shocks following Equation 3. Table 2 contains the values of the ten largest Romer and Romer shocks in absolute value. The largest data points in absolute value happen during the Volcker chairmanship at the Fed, where three of the quarters from 1980 being in the top 4 largest values. This was a feature of the shocks produced in the original Romer and Romer (2004) paper as well. It is also important to note that the first three quarters of 1980 were recessions by the NBER majority rule metric. This is problematic since of the 160 quarters in our sample, only 27 quarters are counted as recessions in the NBER majority rule metric. Since there are so few data points, they are highly susceptible to the influence of outliers.

Figure 6
Quarterly Non-linear Romer and Romer Shocks



Notes: This Figure plots the non-linear Romer and Romer shocks updated to include the sample 1969:Q1-2008:Q4. A feature of these shocks are the large outliers during the Volcker period of the Federal Reserve with the largest coming mostly between the years 1979-1982.

Figure 7 shows the impulse response of the first difference of real GDP with a dummy variable for 1979:Q4-1982:Q4 added into Equation 1. In this case, the recession response is always below the expansion response, indicating that the response of output during recessions is larger than the response during expansions. In contrast with Figure 4, controlling for these outliers moved the conclusion from inconclusive to monetary policy being more effective in recessions. The peak response in recessions is measured to be about three times larger when

Table 2
Quarterly Non-linear Romer and Romer Shocks Ranked

Quarter	**Value**	$NBER_{mr}$
1980:Q2	-2.6377	1
1979:Q4	2.6151	0
1980:Q1	2.1771	1
1980:Q4	1.9366	0
1973:Q4	-1.6411	0
1981:Q2	1.3189	0
1971:Q4	-1.2106	0
1970:Q3	-1.1734	1
1984:Q4	-1.1583	0
1975:Q1	-1.1531	1

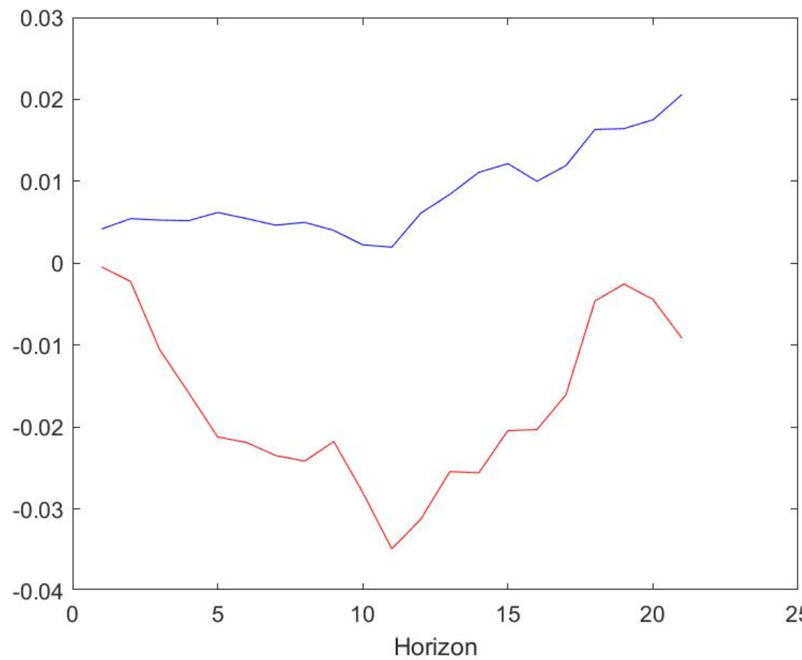
Notes: This Table contains the values of the ten largest shocks (in absolute value) of the Romer and Romer shock series. The column $NBER_{mr}$ is 1 if the quarter was in a recession and 0 if the quarter was in an expansion.

I control for the Volcker period. Also, the expansion results in the baseline case appear to be driven by the Volcker period, since the response in expansions went from significant in Figure 4 to zero in Figure 7. If I compare this to the baseline results by controlling for both stochastic trends in the data and the Volcker period, this completely flips the result of monetary policy being more effective during expansions.

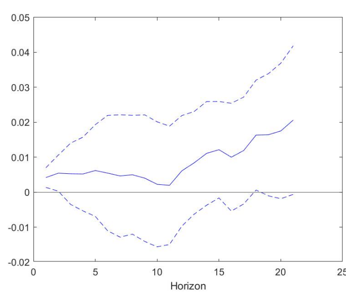
Figures 7b and 7c explore if the cumulated growth rates in expansions and recessions are significantly different from zero. The response of output in expansions is not significantly different from zero anywhere of interest. The recession growth rate is significant for a large portion of the horizon, from horizons 2-17. Given that the recession response is always larger and significant, there are already signs that asymmetry exists in this specification.

The results of the t-test for asymmetry in the cumulative response between expansions and recessions is presented in Figure 7d. This Figure shows that the differences that appeared in the other three graphs are indeed significant. Horizons 2-17 all show p-vlues that are significant at any conventional level, indicating that asymmetry does exist and the response of real GDP to a monetary shock is larger in recessions.

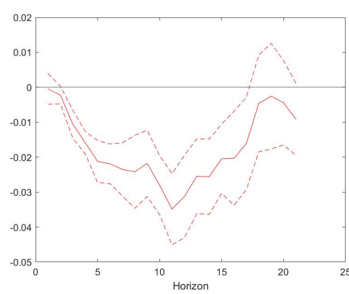
Figure 7
Impulse Response Function of Quarterly real GDP using the Growth Rate Specification with a Volcker Period Dummy



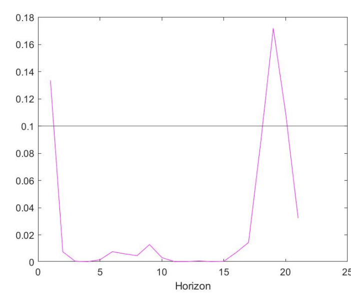
(a) Point Estimates



(b) Expansion



(c) Recession



(d) t-test p-value

Notes: This Figure shows the impulse response of real GDP growth in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in logged first difference. The sample is quarterly from 1969:Q1-2008:Q4 with the years 1979:Q4-1982:Q4 dummied out. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of real GDP with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of real GDP in expansions and recessions with the line in the figure corresponding to the 90% significance level.

The evidence for quarterly real GDP growth with a Volcker dummy does strongly suggest that monetary policy is more effective in recessions. Monthly industrial production growth tells a similar story. Figure 8a is identical to Figure 7a in that the response during recessions is always larger than the response during expansions. Comparing Figure 8a to Figure 5a, does not change the conclusion but does accentuate the difference between the expansion and recession response. The expansion response in Figure 5a while smaller than the recession response is still large. Any expansion response there was vanishes when the Volcker period is controlled for, again suggesting that the Volcker period is driving the expansion results in Figure 5a. Consistent with the quarterly GDP case, the peak response of industrial production in Figure 8a is much larger than in Figure 5a, by a factor of between three and four.

The results from the asymmetry test largely support the result that when industrial production growth and a Volcker period dummy are used, that output responds more to the monetary shock in recessions. The asymmetry t-test has numerous periods where there is a significant difference between the expansion and recession responses and is again significant for a large portion of the horizon, from approximately horizon 5-52. This result is supported by Figures 8b and 8c. The expansion response is not significant at any point over the horizon except for a significant positive response around horizon 8. The recession response is significant from horizon 10-50.

To summarize the results so far, it appears that moving to monthly specifications and industrial production data erases the result that output responds to monetary policy more in expansions than recessions. The peak responses are similar, but there is a timing difference between the expansion and recession responses. Moving to growth rate specifications of output reverses the result for both real GDP and industrial production, while accounting for outliers further accentuates this result. In section 4.5, I explore how these results are impacted by various robustness checks.

4.5 Additional Robustness Checks

Figure 9 explores the robustness of my results to different shock types. I use shocks generated from a non-linear monetary VAR containing real GDP growth, PCE inflation growth, and the Federal Funds rate. The Federal Funds rate is ordered last in the model. The shocks from this VAR were added in place of the Romer and Romer shocks in equation 2. Figure 9 shows the impulse responses and asymmetry tests of real GDP growth to a VAR shock. Figure 10 shows the impulse responses and asymmetry tests of real GDP growth over the same sample period with the Volcker period dummied out as in section 4.4.

Analysis of these two Figures gives the same result as in section 4.4. In Figure 9a, I see inconclusive evidence of which phase of the business cycle has more effective policy. Over the first half of the horizon the effect in expansions dominates while recessions dominate over the later half of the horizon, with both of these being significant. It should be noted that the peak effect of monetary policy is larger in recessions than expansions. Dummying out the Volcker period again causes the response in recessions to increase in size while the response in expansion stays relatively the same between the two graphs. The t-tests do find some significant differences in the cumulative sum of the growth rates between expansions and recessions, finding that the response in recessions is larger at horizons 8 and 20. Overall, the response in recessions is larger than that of expansions for most of the horizon, suggesting that the results shown thus far are robust to the type of shock used.

Figure 11 explores how robust the results are to other measures of economic activity. In this Figure, I use real personal consumption expenditure as the measure of economic activity. Figure 11 shows the impulse responses and asymmetry tests of monthly real PCE over the sample 1969:03-2008:12. Figure 12 does the same analysis but dummies out the Volcker period. In Figure 11a, there are very small to no differences in the response of real PCE to monetary policy in expansions versus recessions. Both responses feature the same peak response that happens slightly earlier in expansions. When I control for the Volcker period, I see a change similar to the one in Figure 10. The expansion response is virtually unchanged while the peak response during recessions increases to approximately four times its original size. The t-test shows that there are now significant differences between the responses in expansions and recessions. Again, controlling for the Volcker period suggests that monetary policy is more effective in recessions than expansions because the impulse response for recessions is always larger than that of expansions over the horizon.

5 Conclusion

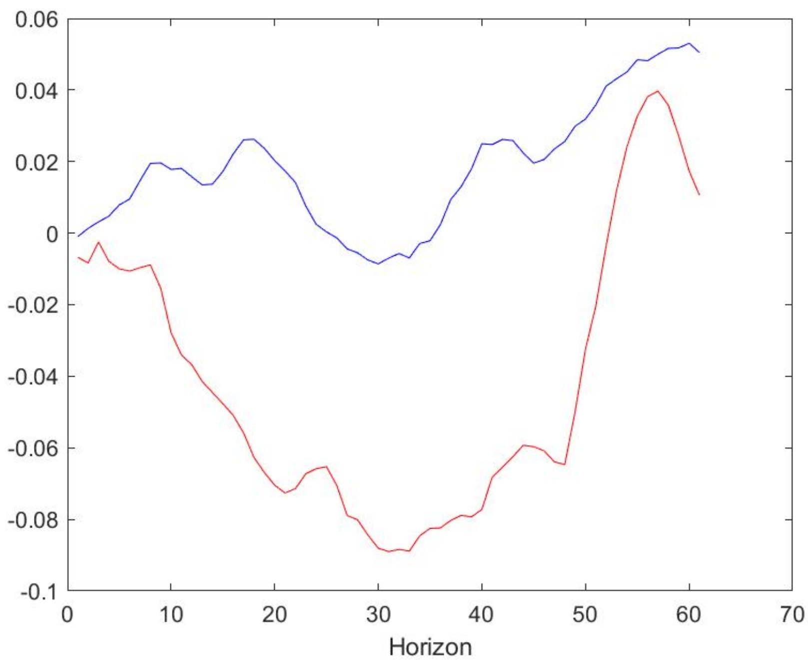
There is substantial evidence in the literature that the effects of monetary policy on output might have different effects in recessions and expansions. Much of the earlier literature on this topic found that monetary policy was more effective in recessions while recent studies have found the opposite to be true. My baseline specification agreed with these recent studies, finding monetary policy to be more effective in expansions. In this paper, I explored some reasons that discrepancies might arise in the literature. This can be narrowed down to three main reasons, which also impacted my baseline result.

First, the frequency of the data and measure of output had an effect on the results. The driving factor behind this is that focusing on interest rate sensitive sectors, such as industrial production, and using monthly recession dates provides a cleaner identification of the effects of monetary policy in expansions and recessions. Switching from quarterly to monthly based measures of output changed the results dramatically. In the quarterly baseline specifications, I found evidence that monetary policy was more effective in expansions than recessions. This result was not robust to switching the measure of output or frequency of data used and the story became one of timing rather than which regime experienced a larger effect. The point estimate in expansions and recessions was largely the same with the estimate in recessions reaching its peak much earlier.

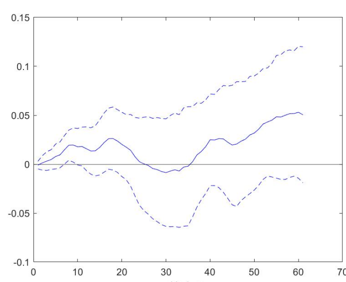
Second, the way that stochastic trends in the data are dealt with also had an effect. Papers earlier in the asymmetry literature favored using growth rates while running levels data has become a more recent trend when using the local projections approach. When I switched the model from running the level of real GDP with a trend to the logged first difference, the asymmetry result from the baseline case disappeared. Instead of the response in expansions being larger, the response in recessions became the same size as during expansions. This leaves us with inconclusive evidence about which regime experienced a larger effect. Both specifications using levels with a trend and logged first difference are correct since they are not inconsistent with a unit root. The unit root tests performed are consistent with a unit root, and if there is one, the differences specification should be more efficient.

Finally, outliers appear to have a major effect on asymmetry. This was a major driving force behind the results since the recession quarters 1980:01-1980:03 featured among the largest shocks in absolute value in the updated Romer and Romer shock series. When a dummy variable is added to the model to control for these outliers, the response during recessions increased in size and the response in expansions disappeared, completely flipping the result from the baseline case. This suggests that the recession outliers were working against finding an effect in the earlier specifications and that a large part of the expansion response in the earlier specifications was being driven by this time period. Recent papers have moved away from recognizing the importance of this time period but the shocks from this period should not be blindly trusted, no matter which type of shock is being used. Given the results of this paper, when the frequency of data and measure of output, stochastic trends, and outliers are considered simultaneously, I find than monetary policy is more effective in recessions than expansions.

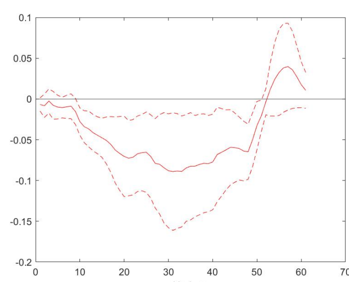
Figure 8
Impulse Response Function of Monthly Industrial Production using the Growth Rate Specification with a Volcker Period Dummy



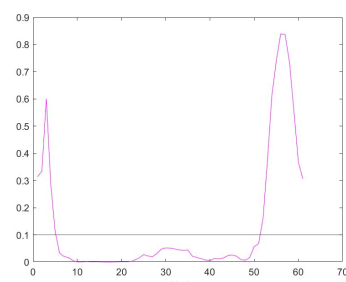
(a) Point Estimates



(b) Expansion



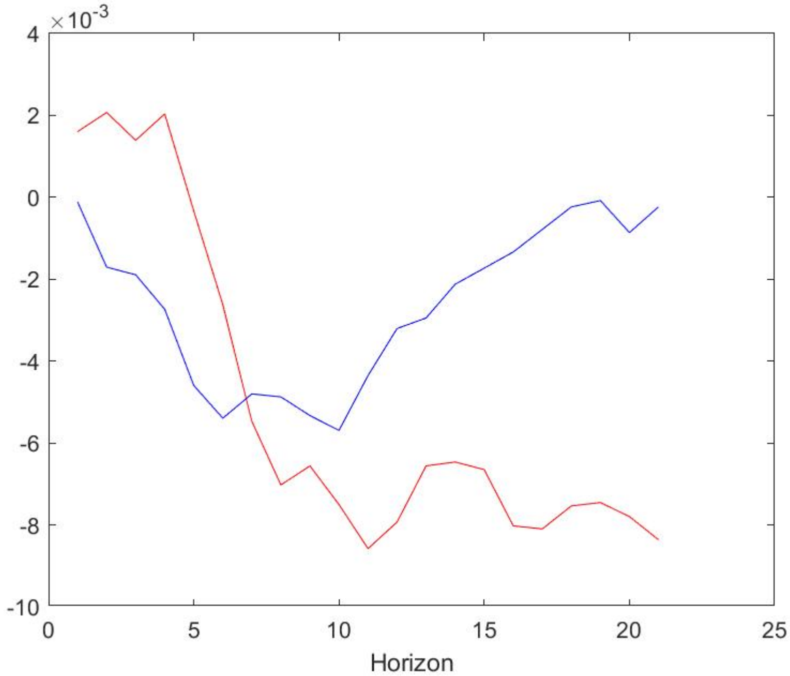
(c) Recession



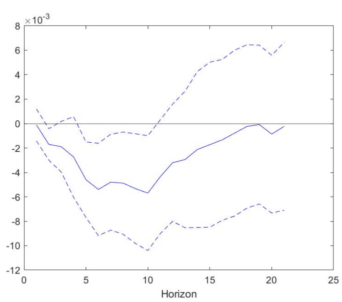
(d) t-test p-value

Notes: This Figure shows the impulse response of industrial production growth in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in logged first difference. The sample is monthly from 1969:03-2008:12 with the years 1979:10-1982:12 dummied out. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of industrial production with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of industrial production in expansions and recessions with the line in the figure corresponding to the 90% significance level.

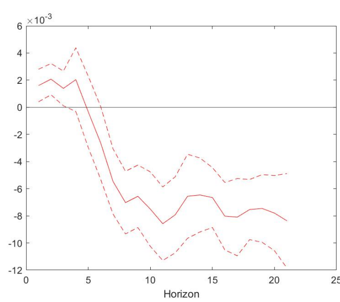
Figure 9
Impulse Response Function of Quarterly real GDP using the Growth Rate Specification to a VAR Shock



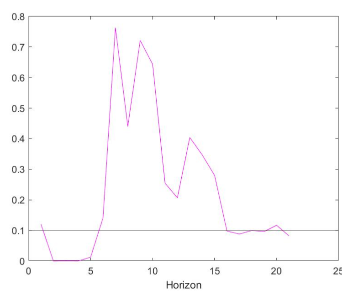
(a) Point Estimates



(b) Expansion



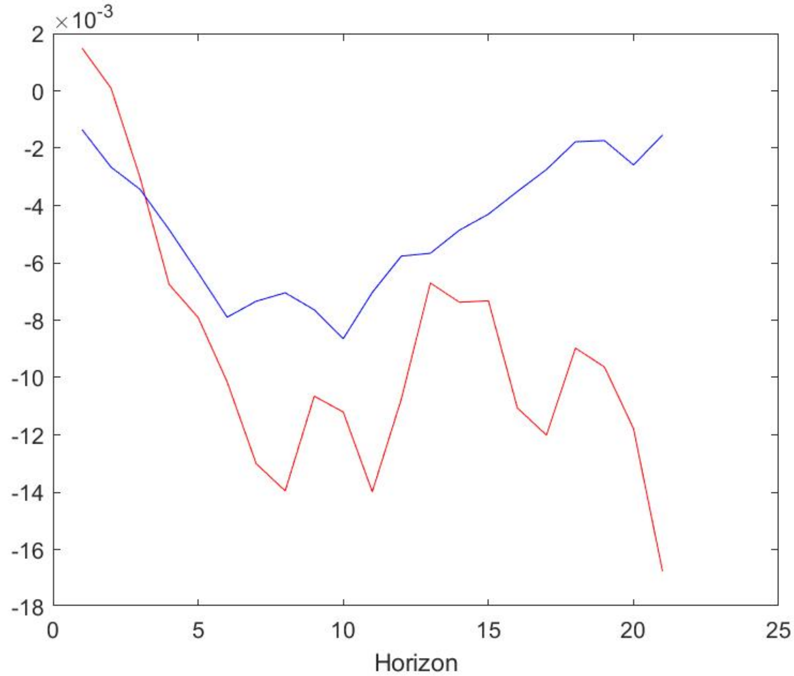
(c) Recession



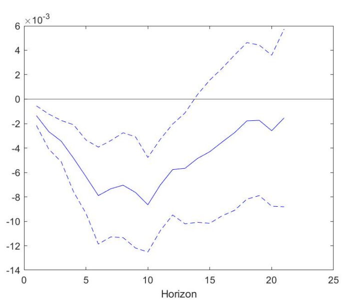
(d) t-test p-value

Notes: This Figure shows the impulse response of real GDP growth in recessions (red) versus expansions (blue) to a positive VAR shock generated from a VAR model containing real GDP, PCE inflation, and the Federal Funds rate. Variables are in logged first difference. The sample is quarterly from 1969:Q1-2008:Q4. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of real GDP with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of real GDP in expansions and recessions with the line in the figure corresponding to the 90% significance level.

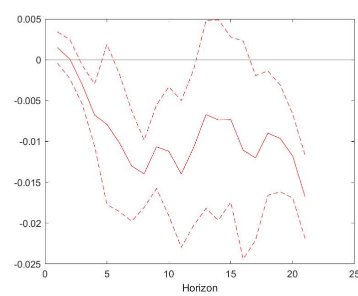
Figure 10
Impulse Response Function of Quarterly real GDP using the Growth Rate Specification to a VAR Shock with a Volcker Period Dummy



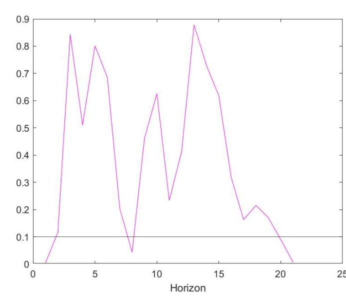
(a) Point Estimates



(b) Expansion



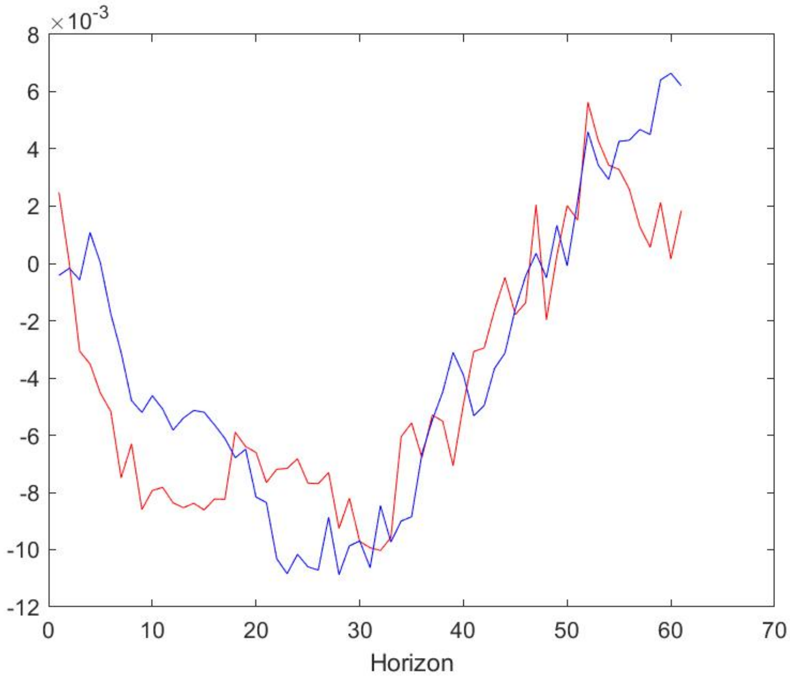
(c) Recession



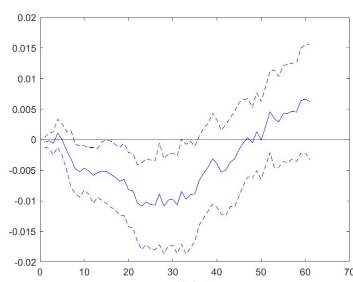
(d) t-test p-value

Notes: This Figure shows the impulse response of real GDP growth in recessions (red) versus expansions (blue) to a positive VAR shock generated from a VAR model containing real GDP, PCE inflation, and the Federal Funds rate. Variables are in logged first difference. The sample is quarterly from 1969:Q1-2008:Q4 with the years 1979:Q4-1982:Q4 dummied out. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of real GDP with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of real GDP in expansions and recessions with the line in the figure corresponding to the 90% significance level.

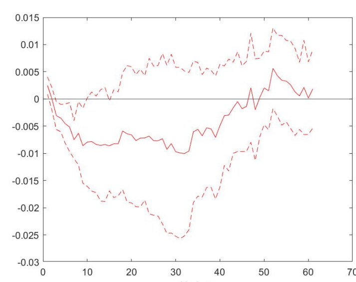
Figure 11
Impulse Response Function of Monthly real Personal Consumption Expenditure Growth using the Growth Rate Specification



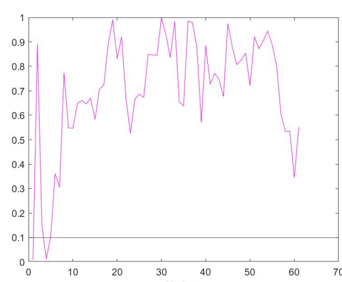
(a) Point Estimates



(b) Expansion



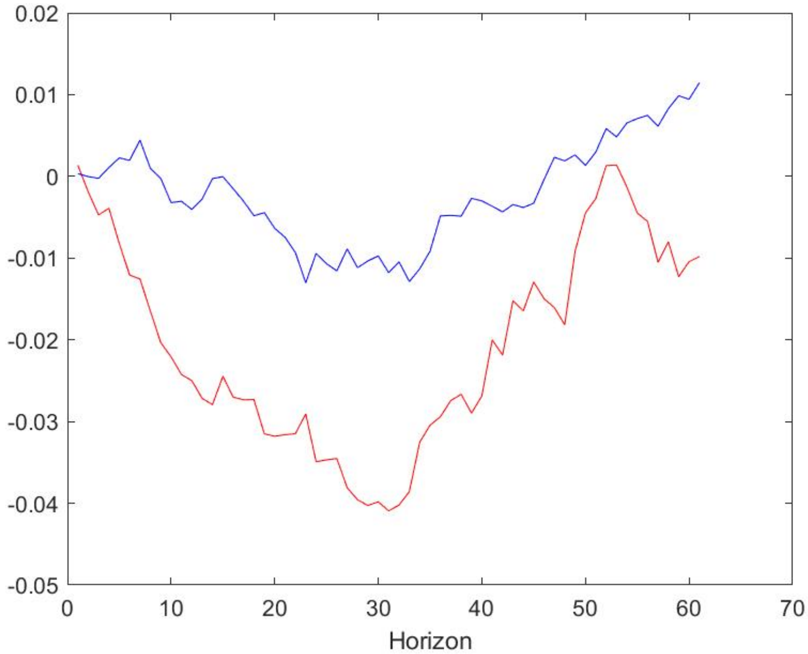
(c) Recession



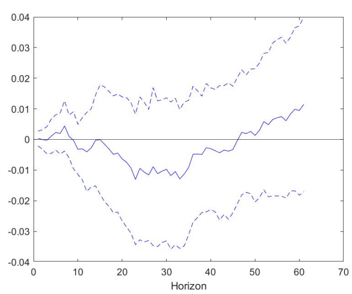
(d) t-test p-value

Notes: This Figure shows the impulse response of real personal consumption expenditure growth in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in logged first difference. The sample is monthly from 1969:03-2008:12 with the years 1979:10-1982:12 dummied out. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of industrial production with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of industrial production in expansions and recessions with the line in the figure corresponding to the 90% significance level.

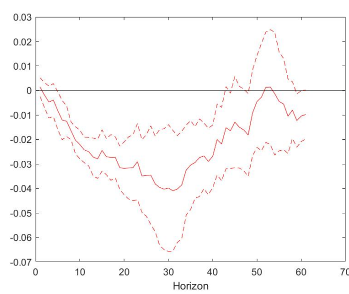
Figure 12
Impulse Response Function of Monthly real Personal Consumption Expenditure using the Growth Rate Specification with a Volcker Period Dummy



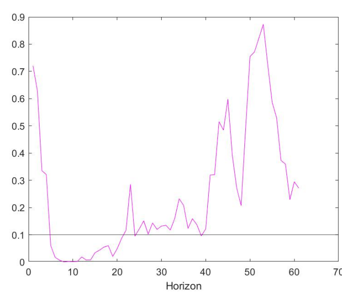
(a) Point Estimates



(b) Expansion



(c) Recession



(d) t-test p-value

Notes: This Figure shows the impulse response of real personal consumption expenditure growth in recessions (red) versus expansions (blue) to a positive Romer and Romer shock. Variables are in logged first difference. The sample is monthly from 1969:03-2008:12 with the years 1979:10-1982:12 dummied out. Figure (a) shows the impulse response point estimates for expansions and recessions where the point estimate is the cumulative sum of the growth rate. Figure (b) and (c) show the impulse responses of the growth rate of industrial production with the Newey-West 90% confidence intervals for expansion and recession respectively. Figure (d) shows the p-value of the t-test for the difference between the growth rates of industrial production in expansions and recessions with the line in the figure corresponding to the 90% significance level.

References

Anderson, H. and T. Teräsvirta (1992). Characterizing nonlinearities in business cycles using smooth transition autoregressive models. *Journal of Applied Econometrics 7*(S), S119–136.

Angrist, J., O. Jordá, and G. Kuersteiner (2018). Semiparametric estimates of monetary policy effects: String theory revisited. *Journal of Business and Economic Statistics 36*(3), 371–387.

Bernanke, B. and M. Gertler (1995). Inside the black box: The credit channel of monetary policy transmission. *Journal of Economic Perspectives 9*(4), 27–48.

Cover, J. (1992). Asymmetric effects of positive and negative money-supply shocks. *The Quarterly Journal of Economics 107*(4), 1261–1282.

Garcia, R. and H. Schaller (2002). Are the effects of monetary policy asymmetric? *Economic Inquiry 40*(1), 102–119.

Gospodinov, N., A. M. Herrera, and E. Pesavento (2013). Unit roots, cointegration, and pretesting in var models. *VAR Models in Macroeconomics - New Developments and Applications: Essays in Honor of Christopher A. Sims*, 81–115.

Granger, C. and T. Teräsvirta (1993). *Modelling Non-Linear Economic Relationships.* Oxford: Oxford University Press.

Jordá, O. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review 95*(1), 161–182.

Kandil, M. (1995). Asymmetric nominal flexibility and economic fluctuations. *Southern Economic Journal 61*(3), 674–695.

Karras, G. (1996). Why are the effects of money-supply shocks asymmetric? convex aggregate supply or "pushing on a string"? *Journal of Macroeconomics 18*(4), 605–619.

Kaufmann, S. (2002). Is there an asymmetric effect of monetary policy over time? a bayesian analysis using austrian data. *Empirical Economics 27*(2), 277–297.

Kilian, L. and Y. J. Kim (2011). How reliable are local projection estimators of impulse responses? *The Review of Economics and Statistics 93*(4), 1460–1466.

Lo, M. C. and J. Piger (2005). Is the response of output to monetary policy asymmetric? evidence from a regime-switching coefficients model. *Journal of Money, Credit and Banking 37*(5), 865–887.

Morgan, D. P. (1993). Asymmetric effects of monetary policy. *Federal Reserve Bank of Kansas City Economic Review 78*(2), 21–33.

Peersman, G. and F. Smets (2002). *Monetary Transmissions in Diverse Economies*. Cambridge, UK: Cambridge University Press.

Ramey, V. and S. Zubairy (2018). Government spending multipliers in good times and in bad: Evidence from u.s. historical data. *Journal of Political Economy April*, 850–901.

Ravn, M. and M. Sola (2004). A reconsideration of the empirical evidence on the asymmetric effects of money-supply shocks: Positive vs. negative or big vs. small? *Quarterly Review Federal Reserve Bank of St. Louis September/October*, 41–60.

Romer, C. D. and D. H. Romer (2004). A new measure of monetary shocks: Derivation and implications. *American Economic Review 94*(4), 1055–1084.

Sims, C. A., J. H. Stock, and M. W. Waton (1990). Inference in linear time series models with some unit roots. *Econometrica 58*(1), 113–144.

Stock, J. H. and M. W. Waton (2018). Identification and estimation of dynamic causal effects in macroeconomics using external instruments. *Economic Journal 128*(610), 917–948.

Tenreyro, S. and G. Thwaites (2016). Pushing on a string: Us monetary policy is less powerful in recessions. *American Economic Journal: Macroeconomics 8*(4), 43–74.

Thoma, M. A. (1994). Subsample instability and asymmetries in money-income causality. *Journal of Econometrics 64*(1-2), 279–306.

Weise, C. (1999). The asymmetric effects of monetary policy: A nonlinear vector autoregression approach. *Journal of Money, Credit and Banking 31*(1), 85–108.