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Do inflation expectations propagate the inflationary impact of real oil price shocks?: Evidence from the Michigan survey*

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Abstract

This paper presents evidence that inflation expectations, as measured by the Michigan Survey of consumers, only play a minimal role in the propagation of real oil price shocks into inflation. This is despite evidence which confirms inflation expectations are sensitive to real oil price shocks. Further analysis exploring structural breaks suggest at some point after the mid-1990s, inflation expectations may have played no part in propagating real oil price shocks into inflation.

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1 Introduction

A key accepted principle for the successful conduct of monetary policy is the ability to manage and anchor inflation expectations. It will then come as no surprise that we observe policymakers are concerned with how to manage inflation expectations in the event of an oil price shock (see, e.g. Mishkin, 2007; Bernanke, 2007). There is an abundance of empirical evidence which suggest inflation expectations are sensitive to oil price shocks (see, *inter alia*, Harris et al., 2009; Coibion and Gorodnichenko, 2014). Therefore, concerns that inflation expectations, whether through the price setting or wage bargaining mechanism, is a possible channel where oil price shocks can feed into inflation are not unfounded. Understanding the causal mechanism on whether and how higher inflation expectations feed into higher realised inflation after oil price shocks is thus crucial in aiding our understanding of the oil price inflation relationship.

The contribution of this paper is to directly evaluate the aforementioned mechanism. We can conceptualise inflation arising from oil price shocks as two broad components. First round effects, or the cost channel, occur largely through increased energy cost feeding directly into higher input cost. Second round effects pertain directly to increases in inflation through the price setting or wage bargaining channel from higher inflation expectations (see, e.g. Barsky and Kilian, 2002; Blinder and Rudd, 2012). From this perspective, the main contribution of this paper is to quantify second round effects given this is the component of inflation from oil price shocks which is attributable to inflation expectations. I first estimate a Structural Vector Autoregression (SVAR) using a survey measure of inflation expectations from the Michigan Survey. I then use the relationships from the estimated SVAR to generate counterfactuals in order to address the relevance of the relationship between oil prices and inflation expectations for understanding inflation dynamics. In particular, I consider a counterfactual where inflation expectations are insensitive to real oil price shocks. The intuition is that if inflation expectations matters in the transmission of oil price shocks into inflation, then we can expect the counterfactual inflation dynamics to differ substantially. It is worth pointing out that an observation that inflation expectations and inflation co-moving in the same direction after an oil price shock is insufficient for establishing inflation expectations as a channel for propagating oil price shocks. As an example, suppose inflation and inflation expectations are mutually delinked, but both respond to oil price shocks. In this case, inflation and inflation expectations can both rise in response to oil price shocks, even in the absence of an explicit mechanism linking them. The approach taken is designed to explicitly study the link between inflation expectations and inflation, conditional on an oil price shock, and so can shed light on whether inflation expectations matter for the transmission of oil price shocks into actual inflation.

Methodologically, the paper fits within a growing strand of literature which models survey data of expectations in a VAR framework (e.g. Barsky and Sims, 2012; Leduc and Sill, 2013). Most relevant is work by Leduc et al. (2007), Harris et al. (2009), Blanchard and Galí (2010) and Davis (2014), who all investigate oil price shocks as possible triggers for inflation through inflation expectations. Relative to their work, my contribution deviates on one crucial dimension. I consider the role of inflation expectations in propagating oil price shocks by generating counterfactuals rather than relying solely on estimated impulse response functions or historical decompositions.

The results first confirm real oil price shocks affects both inflation and inflation expectations. Even so, the second round effects of real oil price shocks appear modest and may even have disappeared sometime after the mid-1990s. Inflation observed in the aftermath of real oil price shocks, at least since 1983, appears to be mostly first round effects and look to have little to do with inflation expectations.

The rest of the paper is organised as follows. Section 2 describes the empirical specification. Section 3 presents the counterfactual analysis while Section 4 attempts to reconcile the empirical analysis with a hypothesis regarding the missing deflation during the Great Recession. The final section presents some concluding remarks.

2 Empirical Specification

Before motivating the empirical model and presenting some baseline results, I will first discuss the Michigan Survey data, which will be the measure of inflation expectations.

2.1 Michigan Survey of Consumer Inflation Expectations

The measure of consumers' inflation expectations is from the University of Michigan Survey of Consumers, also colloquially referred to as the Michigan Survey. Every month, 500 households throughout the United States are surveyed for 1 and 5-10-year ahead inflation expectations. As commonly practised, the median is taken from the survey to quantify inflation expectations (e.g., Ang et al., 2007; Zhang et al., 2008; Harris et al., 2009).[1]

A natural question is whether the Michigan Survey, as a household survey, is an appropriate measure of inflation expectations compared to surveys done on industry professionals like the Survey of Professional Forecasters (SPF). At a conceptual level, it is firms' inflation expectations, which in turn influence their price setting decisions, that matters. Firm level inflation expectations data for the U.S. does not exist. The issue, therefore, is whether the Michigan Survey is a good proxy for firms' inflation expectations. From this perspective, there is little evidence to suggest that the Michigan Survey is inappropriate.

[1] More information regarding the survey can be found at http://www.sca.isr.umich.edu/survey-info.php.

For example, Ang et al. (2007) show that the Michigan Survey provides good inflation forecasts. Coibion and Gorodnichenko (2014) also argue and present evidence that about two thirds of firms in the United States are small and medium enterprises which are unlikely to be hiring a professional forecaster, and so firms' inflation expectations are thus more likely to be closer to that of households. From a practical perspective, the Michigan Survey can yield sharper inferences as it is at monthly frequency compared with alternatives which are at most at quarterly frequencies (e.g. SPF, Livingstone Survey). In addition, part of the identification strategy also relies on informational lags, where the use of monthly data can be more appropriate.

2.2 Empirical Model

Consider the following Structural Vector Autoregression (SVAR) model, with the constant suppressed for expository purposes,

$$A_0 y_t = \sum_{i=1}^{p} A_i y_{t-i} + \epsilon_t, \tag{1}$$

where $y_t = [oil_t, \pi_t^e, \pi_t]'$, consists of the natural logarithm of the real price of oil, a survey measure of inflation expectations from the Michigan survey formed at time t, and annualised month on month U.S. CPI inflation respectively. The real oil price series is the refiners acquisition price of imported crude deflated by the U.S. CPI.[2] The A's are coefficient matrices and ϵ_t is a vector of orthogonal structural shocks. The model is estimated with 12 lags to account for the long and variable lags in the transmission of oil price shocks (see Hamilton and Herrera, 2004). The real oil price is modelled as a level as it is a relative price and should theoretically be bounded (see Kilian, 2008, for a discussion).

2.2.1 Identification

Kilian and Vega (2011) show that the oil price is insensitive to U.S. macroeconomic news, at least at monthly frequencies. I thus identify a real oil price shock by assuming the real oil price is pre-determined to the U.S. macroeconomy. This identifying assumption amounts to restricting all the elements in the first row of the A_0 matrix in Equation (1) to be zero apart from normalising the (1,1) element to 1.[3]

Fully identifying the system requires one more restriction. At time t, lags in the release of macroeconomic data means that economic agents are free to form an expectation of

[2] As the U.S. is a net importer of crude oil, using an importer's price captures the impact of developments in the oil market on the U.S. economy (see Kilian, 2008, 2009, for a discussion of relevant measures). Inflation is measured using the U.S. CPI for urban consumers.

[3] A more recent view disentangles oil price shocks into underlying demand and supply shocks in the global crude oil market (Kilian, 2009; Kilian and Murphy, 2014). Akin to Kilian and Edelstein (2009), we can conceptualise the empirical exercise as estimating the average response to a real oil price shock, thus reflecting the composition of the underlying real oil price shocks within the sample period.

future inflation, even if inflation at time t is not known. By this reasoning, there will be economic shocks that will impact time t inflation which will not be available to economic agents as information when they form their inflation expectations. This argument suggests $A_{0,23} = 0$ as an identifying restriction, reflecting for a mismatch in the timing of when the inflation expectations survey is taken and the release of macroeconomic data. Such an identifying strategy is quite commonly exploited in VARs using survey data. I will follow the convention set by, among others, Leduc et al. (2007) and Clark and Davig (2011), and label the second shock as an inflation expectations shock.

A natural interpretation for this shock is a shock to the economic agents' relevant information sets when forming inflation expectations or forecasting inflation. Some existing work which recursively order survey data above economic variables interpret shocks associated with the survey expectations as possible news shocks (e.g. Barsky and Sims, 2012; Leduc and Sill, 2013). News shocks reflect expectations of future economic conditions. Within the current application, to the extent inflation is a proxy of economic slack, the identified inflation expectations shocks may reflect expectations of future economic conditions. Interpretation of the inflation expectations shock as a news shock can therefore be accommodated within the empirical framework.[4] All the identifying restrictions amount to a recursive ordering of the variables. Note that predetermined real oil prices is sufficient to identify the real oil price shock, regardless how the other shocks are identified.

2.3 Do Oil Prices Move Inflation Expectations?

Following Harris et al. (2009), I only consider data from January 1983 in order to isolate the sample to the post Volcker deflation regime. The 5-10-year ahead inflation expectations data is only available from April 1990. Both samples end in May 2014.

The top panel of Figure 1 presents the median 1-year and 5-10-year ahead inflation expectations from the Michigan Survey. A general observation is that 5-10-year ahead inflation expectations are more stable than 1-year ahead inflation expectations. The middle panel of Figure 1 presents the real oil price. Three known oil market episodes are highlighted. First, the 1986 collapse of OPEC, which caused a sharp decline in the real oil price. Second, the Iraqi invasion of Kuwait in late 1990, which cause a sudden rise, followed by a reversion of the real oil price when resolution of the war was imminent. Third, the oil surge of the 2000s. Much of the increase in the real oil price occurred from 2007 with the subsequent collapse coinciding with the start of the Great Recession.

The bottom panel presents a historical decomposition of the inflation expectations data

[4]The news shock interpretation *cannot* be accommodated by ordering inflation above inflation expectations in a recursive identification scheme unless one assumes economic agents do not act on news immediately. This alternative identification also ignores the timing of both the survey and data release, which has been explicitly exploited for identification, yielding a model lacking in natural economic interpretation.

estimated using two specifications of the SVAR described earlier. The two specifications only differ with respect to using 1-year ahead or 5-10-year ahead expectations as the measure of inflation expectations. The same three oil market events are also highlighted within the historical decomposition. Movements in the real oil price appear to be reflected in the historical decomposition of inflation expectations, and especially so during the three highlighted episodes. This is true regardless of the choice of the inflation expectations series. In particular, movements in the 5-10-year ahead expectations appear sensitive to real oil price shocks. If we define unanchored inflation expectations as long term inflation expectations are sensitive to shocks (see Bernanke, 2007), the historical decomposition suggests the possibility inflation expectations may not be anchored with respects to real oil price shocks.

The empirical results are consistent with a wide variety of evidence suggesting U.S. inflation expectations are sensitive to real oil price shocks (see, *inter alia*, Harris et al., 2009; Beechey et al., 2011; Trehan, 2011; Arora et al., 2013; Ehrmann et al., 2014; Coibion and Gorodnichenko, 2014). Even so, establishing inflation expectations are sensitive to real oil price shocks does not necessarily imply that they must play a role in propagating real oil price shocks. In the next section, this is addressed through the use of a suitable counterfactual.

3 Counterfactual Analysis

If a real oil price shock causes movement in inflation expectations *which subsequently feeds into inflation*, I define this as a second round effect. Note that even if inflation expectations rise as a result of real oil prices, this does not immediately imply a second round effect since this requires any heightened inflation expectations to feed into inflation.[5]

The argument above underpins the intuition behind the counterfactual analysis. One could construct a counterfactual where inflation expectations are *insensitive* to real oil price shocks, thereby isolating first round effects. If inflation expectations are an important channel in propagating real oil price shocks, the counterfactual inflation impulse response function will deviate substantially from the estimated baseline where inflation expectations are unconstrained. To generate the counterfactuals, I feed in a sequence of inflation expectations shocks just large enough to mute out the inflation expectations response after a real oil price shock. This approach to constructing counterfactuals is similar to that by Sims and Zha (2006), Kilian and Lewis (2011) and Bachmann and Sims

[5]The language of second round effects is unfortunate within the context of the paper because it implies a notion of sequencing with regards to inflation from real oil price shock. To be clear, second round effects in this paper will imply any form of inflation arising due to inflation expectations. Therefore, first and second round effects, defined within the context of the paper, differ only with regards to the mechanism they feed into inflation, and and abstracts away from any notion of timing.

(2012).[6] To construct the counterfactual, we first define the SVAR in Equation (1), in companion form,

$$
\begin{aligned}
A_0 y_t &= \sum_{i=1}^{p} A_i y_{t-i} + \epsilon_t \\
y_t &= \sum_{i=1}^{p} A_0^{-1} A_i y_{t-i} + A_0^{-1}\epsilon_t \\
X_t &= \Lambda X_{t-1} + v_t \\
where, X_t &= \begin{pmatrix} y_t \\ y_{t-1} \\ \vdots \\ y_{t-p+1} \end{pmatrix}, \Lambda = \begin{pmatrix} A_0^{-1}A_1 & \dots & \dots & A_0^{-1}A_p \\ I & 0 & \ddots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \dots & \dots & I & 0 \end{pmatrix}, v_t = \begin{pmatrix} A_0^{-1}\epsilon_t \\ 0 \\ \vdots \\ 0 \end{pmatrix}.
\end{aligned}
$$

Let $\mathbb{E}(v_t' v_t) = \Omega$. We first define $\tilde{A}_0^{-1} = chol(\Omega)$ and e_j as a selector row vector with 1 as the j^{th} element and zero elsewhere. The impulse response function of variable j to a 10% real oil price shock at horizon k, Ψ_j^k, is

$$\Psi_j^k = e_j \Lambda^k \zeta,$$

where $\zeta = \frac{0.1 \times \tilde{A}_0^{-1} e_1'}{e_1 \tilde{A}_0^{-1} e_1'}$. Recalling the real oil price is the first variable in the SVAR, the selector vector thus picks out the first column to select a real oil price shock.[7] Let $\hat{\Psi}_j^k$ be the counterfactual impulse response function counterpart for Ψ_j^k, where the "hat" denotes a counterfactual impulse response function. The goal is to construct a sequence of structural shocks, $\hat{\epsilon}_k^{\pi^e}$, to offset the response of inflation expectations to a 10% real oil shock for all k horizons. In other words, we are solving for a sequence of shocks so that $\hat{\Psi}_2^k = 0$, $k \in \mathbb{N}$. The subscript 2 recognises inflation expectations as the second variable in the SVAR. For $k = 0$, we require

$$e_2 \zeta + e_2 \tilde{A}_0^{-1} e_2' \hat{\epsilon}_0^{\pi^e} = 0.$$

It is clear $\epsilon_0^{\pi^e} = -\frac{e_2 \zeta}{e_2 \tilde{A}_0^{-1} e_2'}$. The rest of the sequence can be calculated recursively through

$$\hat{\epsilon}_k^{\pi^e} = \frac{\Psi_2^k + \sum_{n=0}^{k-1} e_2 \Lambda^n \tilde{A}_0^{-1} e_2' \hat{\epsilon}_n^{\pi^e}}{e_2 \tilde{A}_0^{-1} e_2'}, k \in \mathbb{N}$$

[6] A natural question is whether the counterfactual conflicts with the Lucas Critique. The empirical relevance of the Lucas Critique in VARs using U.S. postwar data appears limited (e.g. Rudebusch, 2005; Sims and Zha, 2006), providing support for the validity of the empirical exercise. Other means of constructing counterfactuals are explored in the online appendix.

[7] The difference between $\tilde{A}_0^{-1}$ and A_0^{-1} is a normalisation where the latter is normalised to have 1 on it's diagonal.

The counterfactual impulse response function for all variables to a real oil price shock with inflation expectations held fixed, $\hat{\Psi}_j^k$, can be computed

$$\hat{\Psi}_j^k = \Psi_j^k + \sum_{n=0}^{k-1} e_j \Lambda^n \tilde{A}_0^{-1} e_2' \hat{\epsilon}_n^{\pi^e}, j = \{1, 2, 3\} .$$

3.1 Counterfactual Results

Figures 2 compares the impulse response functions estimated from the SVAR model and the associated counterfactual where inflation expectations, using 1-year ahead and 5-10-year ahead expectations respectively, are insensitive following a real oil price shock. The solid line and shaded areas are the estimated impulse response function and error bands to a 10% exogenous increase in the real oil price. The dotted line represents the counterfactual impulse response function. The leftmost subplot presents the inflation expectations response with the middle and rightmost subplots respectively present the annualised month on month CPI inflation, and the cumulative (non-annualised) log differences from the inflation impulse response functions in order to study the overall impact on the CPI level. Regardless of whichever inflation expectations series is used, it appears inflation expectations move in the event of a real oil price shock. This is consistent with the historical decompositions which suggest inflation expectations are sensitive to real oil price shocks.

We first focus on the specification with 1-year ahead inflation expectations, estimated on data starting in January 1983, presented in the top panel (a) of Figure 2. The counterfactual suggest an initial burst of CPI inflation, similar to the inflation responses where inflation expectations are left unconstrained. This is to some extent not surprising, because we do not expect the first round effect of inflation to be mitigated. Even so, we can observe in the counterfactual that inflation falls marginally faster. The overall impact on the CPI price level is marginally lower in the counterfactuals. These results suggest some modest second round effects of real oil price shocks into inflation.

Turning to the longer term inflation expectations data, the bottom panel (b) presents results using the specification with the 5-10-year ahead expectations. The sample starts in April 1990 due to the shorter sample span. An initial burst of CPI inflation also occurs, similar to the results obtained using the 1-year ahead expectations. While the estimated counterfactual suggests the possibility of once again modest second round effects, this is now not statistically significant. Note that even though the specifications using the 1-year ahead and 5-10-year ahead are mismatched, the inflation response of both specifications are very similar.

It is useful to point out that 1-year ahead and 5-10-year ahead expectations do not necessarily contain the same information, and therefore, we do not expect them to perfectly match up. For example, Fuhrer (2011) and Fuhrer et al. (2012) show shorter term inflation expectations are more important than longer term ones in determining inflation. The results here accord well with such analysis given second round effects appear to be more prevalent with the 1-year ahead specification. In order words, evidence of second round effects is more likely to manifest in a specification containing 1-year ahead expectations.

Exploring Possible Structural Break

Even though there is evidence that 1-year ahead and 5-10-year ahead expectations do determine inflation differently, it is still worth exploring possibilities in further reconciling the differences in the results between both specifications. A natural step is explore the mismatch in the respective data samples. I redo the analysis on the 1-year ahead expectations starting from April 1990 to match up with the sample in the 5-10-year ahead expectations. These results are presented in the top subplots of Figure 3. It appears only some elements of the results with the longer data sample survive. The overall impact of the CPI price level is now indistinguishable from the originally estimated response. However, as per the longer sample, inflation still falls marginally faster in the counterfactual, reflected in a statistically significant difference in the CPI price level up to 5 months after the real oil price shock.

While the estimation using the 1-year ahead expectations from April 1990 utilises only post Volcker deflation data, there is evidence which suggests inflation expectations only became more anchored much later, potentially only in the 1990s, and possibly only after 2000 (e.g. Leigh, 2008; Davis, 2012). It is thus not *a priori* obvious whether the lack of second round effects in the shorter sample is due to a loss of statistical power from a shorter sample or potential structural breaks. I use the Qu and Perron (2007) procedure to test for structural breaks in multivariate models. The procedure dates possible breaks in January 2003 and September 2009 for the specification with 1-year ahead expectations and September 1994 for the 5-10-year ahead expectations. The associated 95% confidence intervals using the approach by Eo and Morley (2014) are January 2003 - Feburary 2003 and August 2008 - October 2008 for the 1-year ahead expectations specification and August 1994 - October 1994 for the 5-10-year ahead expectations.

I redo the analysis for the 1-year ahead expectations using a sample from January 1983 - December 2002, the latter is the lower bound of the confidence interval of the break date. The 5-10-year ahead expectations specification is redone starting from the upper bound of the confidence interval of the break date, November 1994.[8] These are presented in the set of middle and bottom subplots of Figure 3.

Using a sample from January 1983 to December 2002, there is evidence of second round

[8] In principle, it would be desirable to account for all possible break regimes detected by the structural break tests. However, the timing of the breaks would leave some subsample periods with less than 10 years of data, making it overly challenging to estimate a VAR with any precision.

effects of real oil price shocks using the 1-year ahead expectations. It is thus suggestive that the main estimation from January 1983 to May 2014 is heavily driven by the data pre-December 2002. Therefore, the results of limited second round effects with the sample from April 1990 is reconcilable with the sample post December 2002 showing little to no second round effects of real oil price shocks.[9] An estimation of the 5-10-year ahead expectations shows little second round effects with a sample post November 1994. While more tenuous, the statistically insignificant second round effects found in the sample from April 1990 is potentially reconcilable with possible second round effects before November 1994.

The results confirm inflation expectations are sensitive to real oil price shocks regardless of structural breaks or the sample period under consideration. This is evidenced by all different specifications showing inflation expectations respond to real oil price shocks. However, the degree to which this sensitivity matters for inflation appears to have changed at some point since the mid-1990s. In particular, there is a lack of second round effects since the 1990s, despite inflation expectations appearing to still be sensitive to real oil price shocks. In an environment where inflation expectations are well anchored, one expects inflation expectations do not respond, and thus inflation should not respond beyond the cost channel, or first round effect. The results in my analysis hints since the mid-1990s or 2000s, inflation from real oil price shocks appears to only be from the cost channel because the link between inflation expectations and inflation may have broken down. It is more speculative as to why this link may have broken down. A well accepted channel where inflation expectations propagate real oil price shocks, namely second round effects, is through the price setting or wage bargaining channel. In this respect, it is not clear that even if one expects higher inflation, one will automatically seek higher wages or increases prices. One possibility is price setting or wage bargaining behaviour may have changed. There is some evidence that such a mechanism may indeed be at work. For example, Akerlof et al. (2000) present evidence how in low and stable inflation environments, the weight of inflation expectations on actual wage and price inflation is less pronounced. In other words, price setters and workers are less likely to factor their inflation expectations into the price setting or wage bargaining process, perhaps because it is more costly to do so. To some extent, it is not entirely surprising an uncovered structural break presents evidence consistent with Akerlof et al. (2000) because one of their empirical specifications uses the Michigan Survey, albeit with a then shorter sample compared to the analysis in this paper.

It is also at least widely accepted at lower average inflation rates, it is costly to change prices (see, e.g. Ball et al., 1988). Average inflation has certainly been lower post mid-

[9] Explicitly estimating the 1-year ahead specification on the two regimes after December 2002 will display no second round effect, but it is worth keeping in mind the low power of tests in the short sample will make it challenging to find evidence of second round effects. In any case, all the results obtained are consistent by inferring no second round effects after December 2002 in the 1-year ahead specification.

1990s, the date of the suggested structural break. Stock and Watson (2007), Cogley et al. (2010) and Chan et al. (2013) show in various specifications that trend, or average, inflation only reach 2% by the mid-1990s, much later after the Volcker disinflation.

While the timing of the breaks can be reconciled with lower trend inflation, it is not appropriate to take an overly speculative stand on the sources of the uncovered structural break apart from reconciling the results with those obtained elsewhere. More work is needed before reaching more concrete conclusions. The only claim that the empirical analysis can make is that second round effects appear to have disappeared, coinciding with the timing that other studies find U.S. inflation expectations to have became more anchored and trend inflation became stable at around 2%.

4 The Great Recession and the Missing Deflation

The sustained weakness in the U.S. economy during and after the Great Recession was not accompanied by deflation that a conventional Phillips Curve would predict. Of related interest to this paper is a hypothesis by Coibion and Gorodnichenko (2014) (henceforth CG) that heightened inflation expectations can largely explain the missing deflation during the Great Recession. CG put forward a mechanism where high oil prices boost inflation expectations and thus can explain the missing the deflation. Given modest to non-existent second round effects within the empirical analysis in this paper, it is difficult to reconcile how a boost of inflation expectations from high oil prices can feed into inflation.

In reconciling my findings with CG, one need to note the empirical setup within this paper is different relative to theirs. CG estimate a regression to first confirm the 1-year ahead Michigan Survey boosted inflation expectations before running a subsequent battery of regressions to show high oil price boosted the Michigan Survey inflation expectations data. Given the conceptual differences between our empirical models, I make a distinction between shocks and endogenous fluctuations given what CG uncover are largely correlations. To first explore movements in real oil prices, and not just limit my analysis to real oil price shocks, I generate a counterfactual inflation series from January 2009 to May 2014, given the real oil price fell by over 70% from July to December 2008 due to the onset of the Great Recession before rising and attaining new highs. I generate a counterfactual inflation and inflation expectations series where the real oil price stays at the level they were at in January 2009.[10] I use the specification with 1-year ahead inflation expectations from January 1983 to May 2014 given it has a tighter link to real oil prices and inflation, and is also consistent with the inflation expectations series CG

[10]In order to generate these counterfactual, I generate a sequence of structural shocks to the real oil price to keep the path of real oil prices flat. These time series are then simulated with the counterfactual sequence of shocks in addition to the actual realised time series of shocks. It is important to note that one should not use reduced form shocks, or set all the structural shocks to zero when computing such counterfactuals as endogenous fluctuations of the respective variables have to also be offset.

consider. I also do not consider the structural break uncovered in the earlier section. All these choices are motivated as giving the best shot at reproducing the mechanism outlined by CG's analysis.

Panel (a) and (b) of Figure 4 respectively present the counterfactual inflation and inflation expectations series with the actual time series. Inflation, if oil prices stayed at the level they were at in January 2009, would not differ by much. At most, there could be deflation in the first half of 2009 in the absence of the pick up in oil prices, but the counterfactual path of inflation after June 2009 does not appear to deviate substantially from the actual path. Inflation expectations are unsurprisingly lower under the counterfactual where real oil prices did not pick up. Even so, inflation expectations are not substantially different as the pickup of inflation expectations to 4% by early 2011 still occurs.

If we focus our attention on real oil price shocks, panel (c) presents the historical decomposition of inflation expectations from January 2009 to May 2014. Shocks other than the real oil price shocks are grouped together. For the entire time period, it is not certain that real oil price shocks were the dominant shock boosting inflation expectations.

In sum, the analysis from the current empirical setup is only able to suggest weak evidence that high oil prices boosted inflation expectations that prevented deflation. There is only partial support for the claim that higher oil prices preventing deflation through inflation expectations given the counterfactual only suggests such a mechanism may be present in early 2009. However, even this is only the best possible case from my empirical setup because the counterfactual is extremely sensitive to choosing a start date from October 2008 to March 2009 when real oil prices collapsed. Note that the analysis here is neither able to reject nor confirm the main thrust of CG's argument that higher inflation expectations prevented deflation. It is worth pointing out that in the counterfactual, inflation expectations did rise even if real oil prices stayed at its trough in January 2009. The historical decomposition during the post 2009 period also shows shocks other than real oil prices did boost inflation expectations, suggesting inflation expectations did rise for a variety of factors. Moreover, it should be pointed out that during the period 2009-2011, many possible causes which are not explicitly modelled could have heightened inflation expectations. These include high food prices to the perceived easy money of quantitative easing. While inflation expectations are sensitive to real oil price shocks, real oil price shocks are by far not the only driver of inflation expectations. All the results are consistent with the main analysis of the paper that while inflation expectations are sensitive to real oil prices, the role they play in propagating real oil price shocks is limited.

5 General Discussion and Conclusion

There is consistent evidence suggesting U.S. inflation expectations are sensitive to real oil price shocks. This may be concerning for policymakers because of the fear that oil price shocks may act as triggers for second round inflation if inflation expectations materialises into higher actual inflation. While the paper broadly find evidence to support the notion that U.S. inflation expectations are sensitive to real oil price shocks, counterfactual analysis where inflation expectations are insensitive reveals the role of inflation expectations in propagating real oil price shocks is quite limited. Therefore, contrary to widespread belief, the results suggest the observation that inflation expectations are sensitive to real oil prices may have little policy relevance, at least since the period of the Volcker disinflation. This, of course, does not suggest one should routinely ignore inflation expectations in the aftermath of real oil price shocks because in a different monetary policy regime, heightened inflation expectations in response to real oil price shocks may indeed materialise into inflation. This is a claim that the current paper cannot provide any insights to. However, the results can claim that in an environment of benign inflation, movements in inflation expectations in response to real oil price shocks appear to have little or nothing to do with actual inflation outcomes.

Interestingly, structural break tests suggest movements in inflation expectations in response to real oil price shocks may have become irrelevant in understanding inflation dynamics at some point after the mid-1990s. While avenues in resolving this finding are less obvious, a possible direction for future work may be to explore whether changes in price setting dynamics may perhaps be the reason explaining this observation.

Recent developments at the time of writing has seen oil prices falling rapidly.[11] These developments have sparked fears of deflation. The mechanism of the deflation risk is similar to the one investigated within this paper, namely inflation expectations.[12] Extrapolating future developments is always challenging. Notwithstanding, the empirical model established within this paper is symmetric, and thus can in principle be used to analyse real oil price shocks in either direction. Within the context of the empirical analysis, it appears unlikely such a mechanism will materialise in the U.S. In addition, the analysis can be easily adapted for economies who face a non-trivial deflation risk through the oil price and inflation expectation mechanism, as long as the data limitations are surmountable. I leave this as an area for future research.

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[11] A common reference point for the oil price is the West Texas Intermediary spot price. This fell from about US$100 to under US$80 a barrel from January 2014 to November 2014.

[12] The Economist, 25 October 2014, Cheaper Oil: Winners and Losers, *"[...] with inflation below its [the Fed] 2% target, it will fret that falling oil prices could be pushing [inflation] expectations down, making it harder to keep inflation on target."*. Peter Praet, Member of the Executive Board of the ECB, October 28 2014, *"That's [the risk of deflation] a concern.. Cheaper oil [...] threatens to drag inflation expectations down too far."*

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Figure 1: Time Series Plots

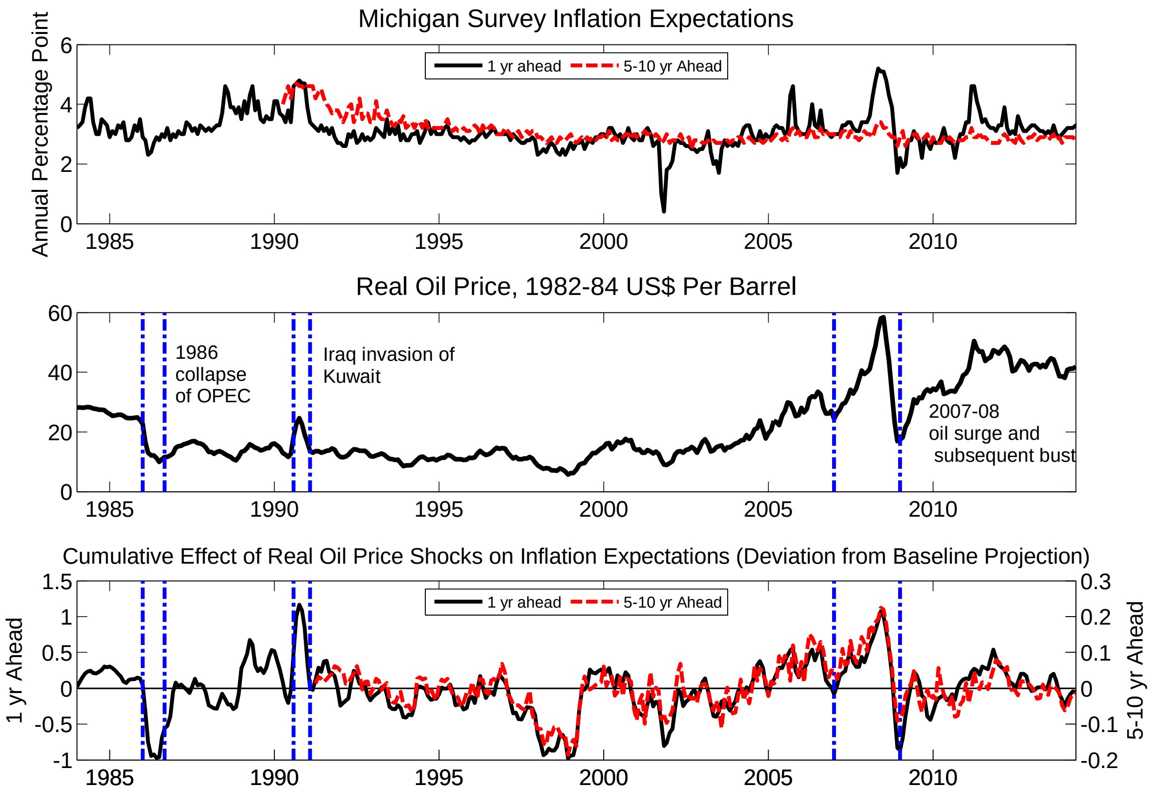
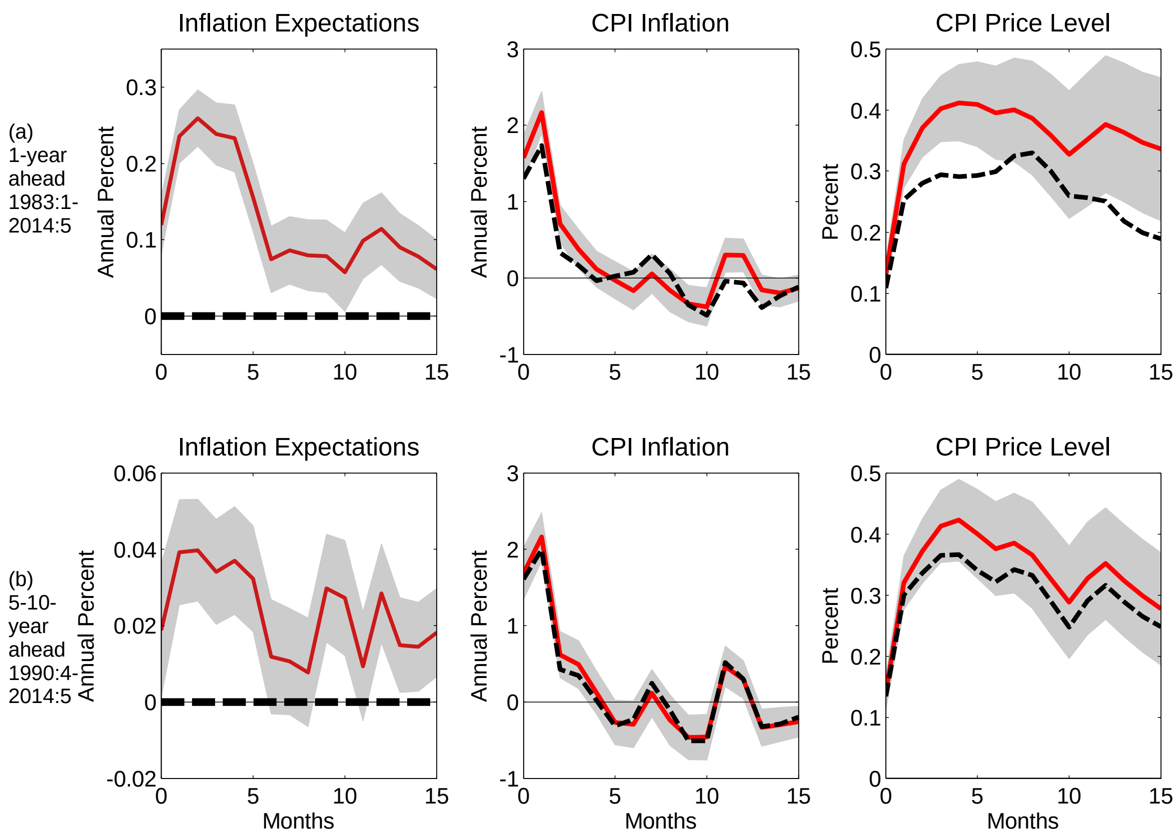
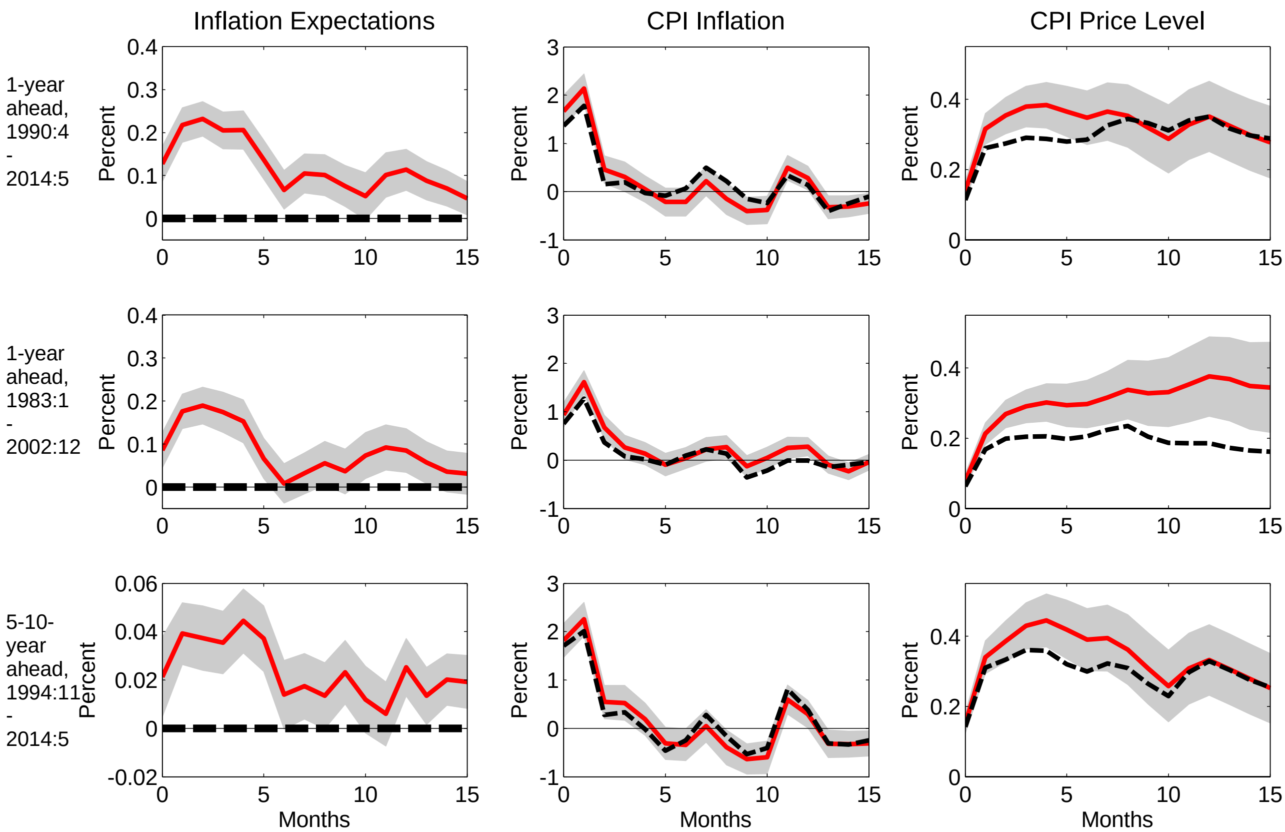


Figure 2: Estimated and Counterfactual Impulse Response Functions to a Real Oil Price Shock



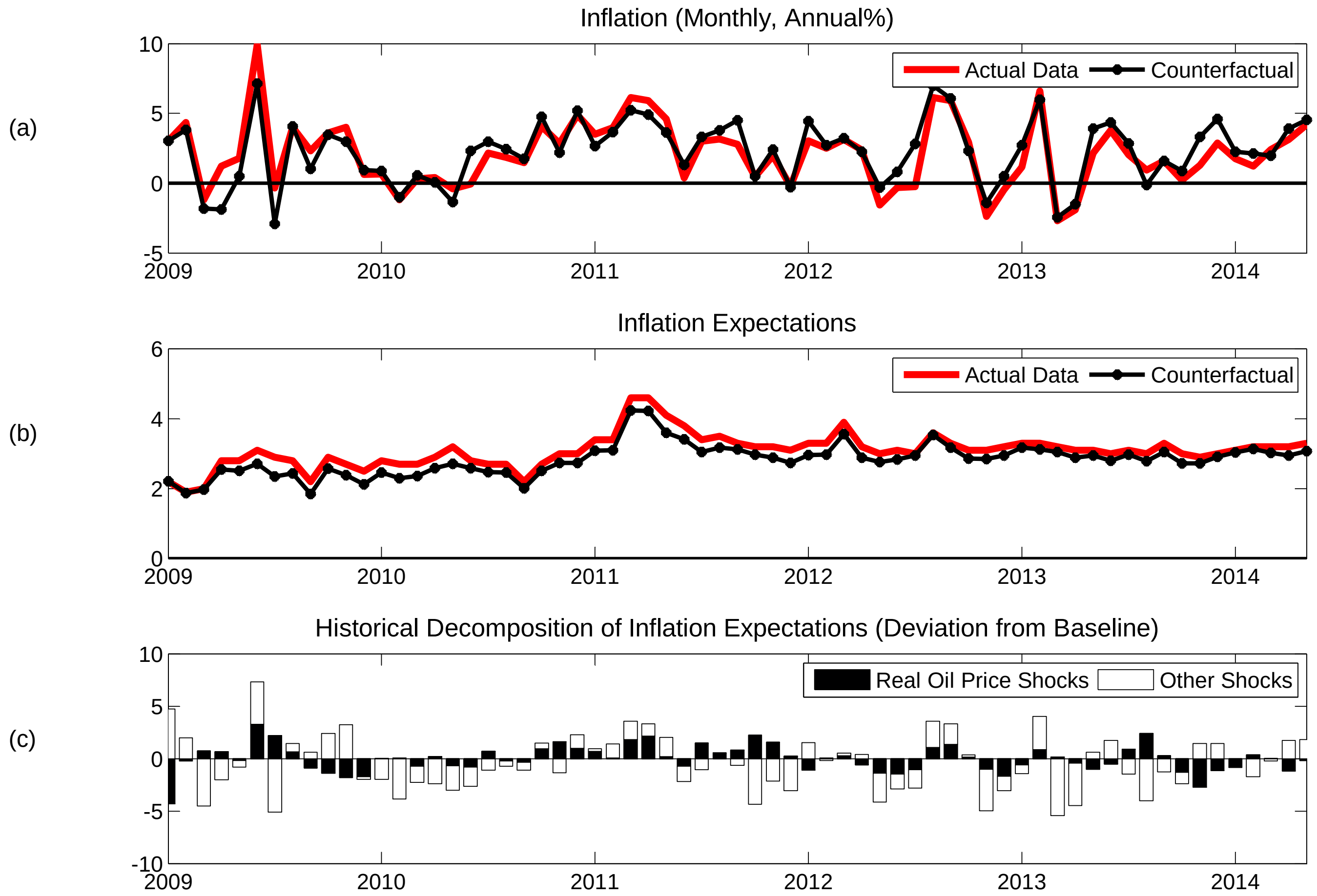
Notes: (a) Top panel presents specification estimated using 1-year ahead inflation expectations in a trivariate VAR.
(b) Bottom panel presents specification estimated using 5-10-year ahead inflation expectations in a trivariate VAR.
Impulse response functions are to an exogenous 10% increase in the real oil price. Shaded areas are one standard deviation error bands computed using the wild bootstrap proposed by Gonçalves and Kilian (2004). Dotted line represents counterfactual when inflation expectations are insensitive to a real oil price shock.

Figure 3: Counterfactual Results using for Various Subsamples



Notes: 1-year ahead and 5-10-year ahead refers to the relevant series for inflation expectations. Solid line represents estimated impulse response function to an exogenous 10% increase in the real oil price. Shaded areas are one standard deviation error bands computed using the wild bootstrap proposed by Gonçalves and Kilian (2004). Dotted line represents counterfactual when inflation expectations are insensitive to a real oil price shock.

Figure 4: Great Recession Counterfactuals



Notes: (a) and (b) are the counterfactual inflation and inflation expectations time series if the real oil price remained flat since January 2009. (c) is the historical decomposition of 1-year ahead inflation expectations from the VAR specification.

Supplementary Material for *"Do Inflation Expectations Propagate the Inflationary Impact of Oil Price Shocks: Evidence from the Michigan Survey"*

Benjamin Wong*

A1 An Alternative Counterfactual

One approach to construct a counterfactual where inflation expectations are insensitive to real oil price shocks is to zero out all the inflation and real oil price terms in the inflation expectations equation. This is presented in Figure A1, which is analogous to Figure 2 in the main paper. The blue line with circle markings represents the counterfactual constructed through the zeroing out of terms in the inflation expectations equation. The black dotted line represents the impulse response function in the main analysis. It appears there are no longer any second round effects with either the 1-year ahead or 5-10-year ahead inflation expectations using the approach of zeroing out terms. If we consider the structural break in January 2003, as uncovered in the main analysis of the paper, this analysis is presented in Figure A2. Second round effects are detected using a specification using the 1-year ahead expectations, consistent with the main body of the paper.

The main results of the paper are that second round effects range from being limited to non-existent since 1983. In particular, there are no second round effects at some point after the mid 1990s. The main qualitative results of the paper are thus robust to this alternative counterfactual approach of zeroing out terms in the inflation expectations equation.

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A2 Decomposing the Second Round Effect

Inflation expectation respond to real oil price shocks within the empirical setup through two channels. For the sake of exposition, I label these as the direct and indirect channel. In the direct channel, inflation expectations are reacting directly to real oil price fluctuations. This channel will include the documented excess sensitivity of inflation expectations, perhaps through the mechanism of constant interaction with petrol prices and gas bills (e.g. Georganas et al., 2014; Ehrmann et al., 2014). In the indirect channel, inflation expectations are not responding to the real oil prices directly, but are elevated because higher real oil prices feed into higher CPI inflation and subsequently into higher inflation expectations. In other words, inflation expectations are heightened *indirectly* through the effect real oil price shocks have on inflation and this may subsequently materialise into inflation within a feedback loop mechanism. The direct and indirect channel provides a means to disaggregate second round effects of real oil price shocks.

The main analysis in the paper constructs a sequence of inflation expectations shock just large enough to fully offset the response of inflation expectations. To quantify the direct and indirect channels of second round effects, the idea is to construct a sequence of shocks large enough to offset only the response of inflation expectation to the contemporaneous and lag terms of either the real oil price (direct channel) or inflation (indirect channel). Note the main counterfactual analysis in the paper mutes out both channels. Kilian and Lewis (2011) provides an exposition on constructing a sequence of shocks to partially instead of fully offset movements of an endogenous variable.

Only the results for the direct and indirect channel is done for the 1-year ahead inflation expectations specification from 1983-2002 as it is the only specification which evidences some degree of second round effect. This is presented in Figure A3. The results indicates evidence of any second round effect appears to be driven by the response of inflation expectations to inflation after a real oil price shock. That is, any second round effect appears most concentrated in a feedback loop type effect that transmits from inflation to inflation expectations and back to inflation after a real oil price shock. In other words, the sensitivity of inflation expectations to real oil prices *per se* does not appear to be useful in understanding second round effect.

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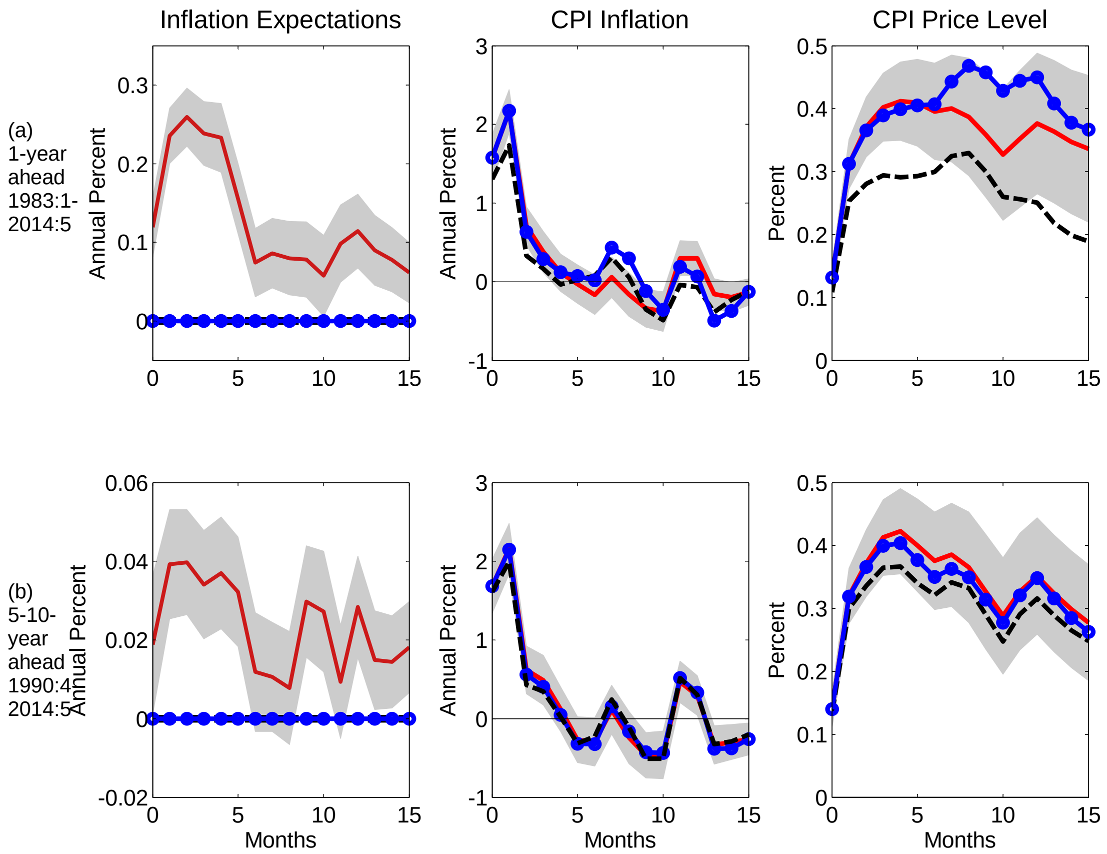
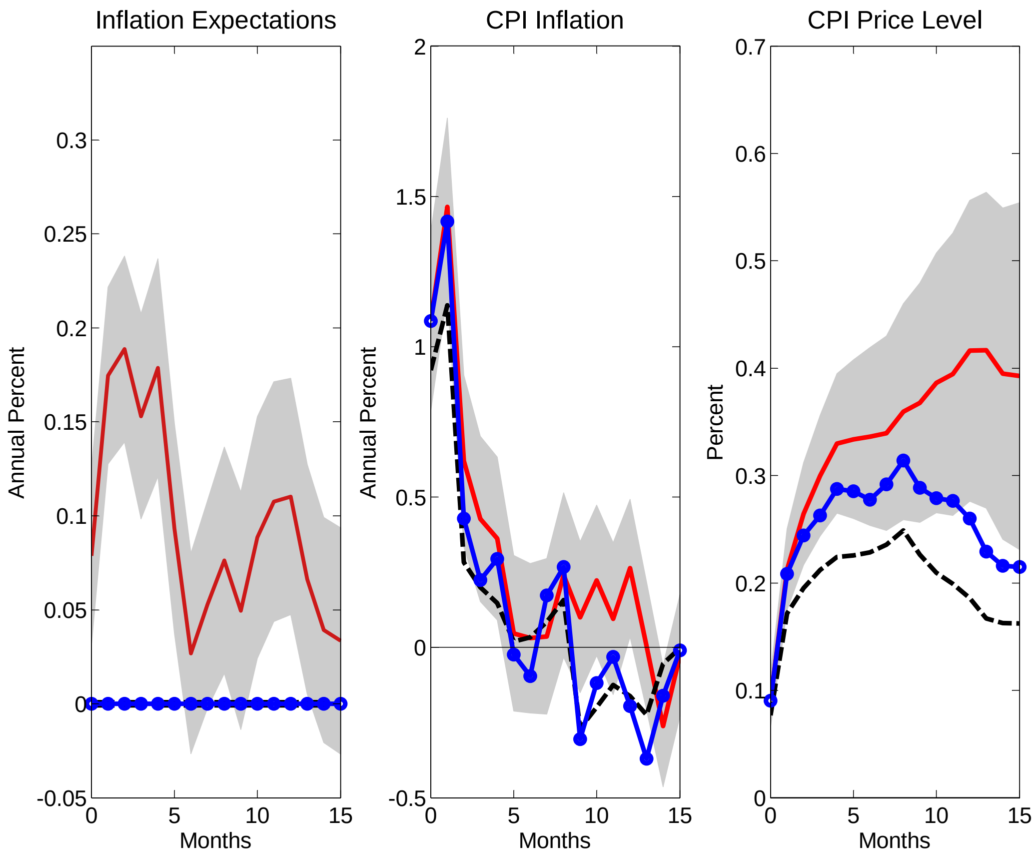
Figure A1: Estimated and Counterfactual Impulse Response Functions to a 10% Real Oil Price Shock



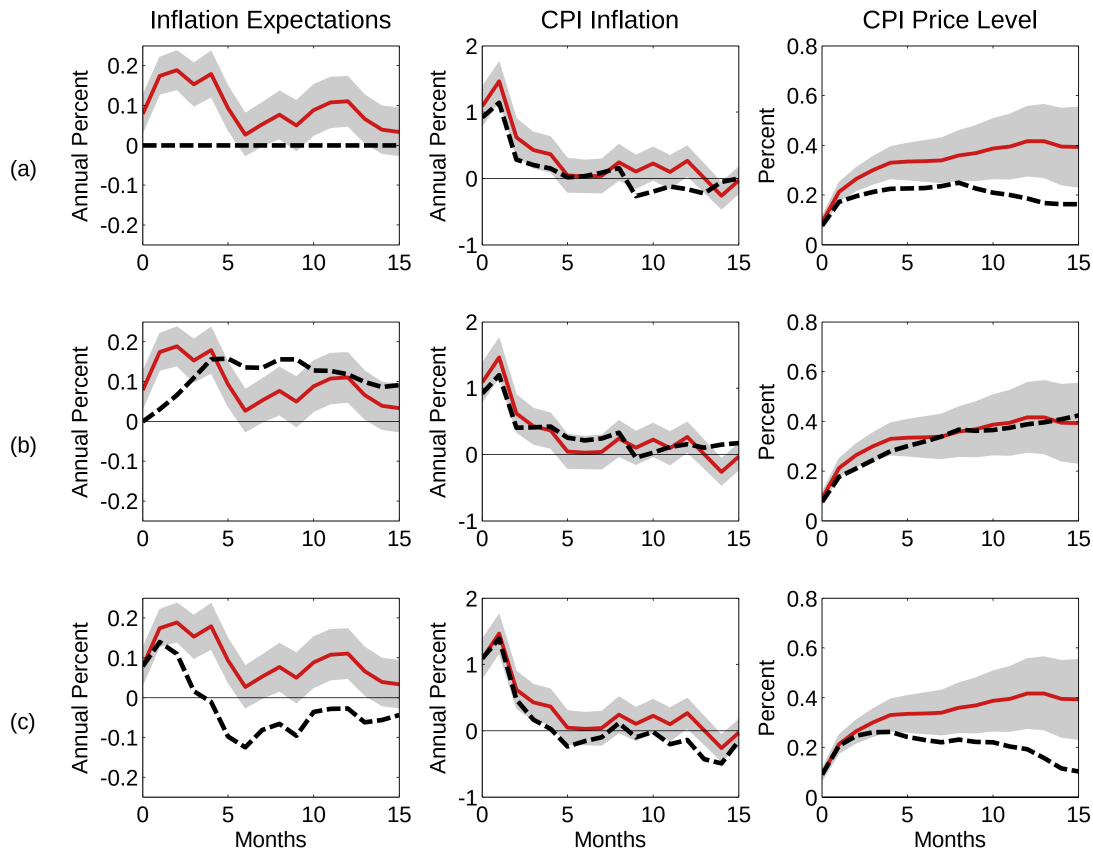
Notes: Solid red line is the response to a 10% oil price shock. Shaded areas are one standard deviation confidence bands. Black dotted line is the counterfactual used in the main analysis within the paper. Blue line with circle markings is the a counterfactual constructed by zeroing out terms in the inflation expectations equation.

Figure A2: Estimated and Counterfactual Impulse Response Functions to a 10% Real Oil Price Shock, January 1983 - December 2002



Notes: Specification uses 1-year ahead inflation expectations. Solid red line is the response to a 10% oil price shock. Shaded areas are one standard deviation confidence bands. Black dotted line is the counterfactual used in the main analysis within the paper. Blue line with circle markings is the a counterfactual constructed by zeroing out terms in the inflation expectations equation.

Figure A3: Estimated and Counterfactual Impulse Response Functions to a Real Oil Price Shock



Notes: Sample period is Jan 1983 - December 2002. Specification uses 1-year ahead inflation expectations. Solid line and shaded areas represent the impulse response function to a 10% exogenous increase in the real oil price and the one standard deviation error band respectively. Dotted line represents the respective counterfactual where inflation expectations are insensitive on various dimensions.

(a) Inflation expectations are fully insensitive after a real oil price shock (main counterfactual in the paper).

(b) Inflation expectations do not respond to the real oil price after a real oil price shock (direct channel of second round effect).

(b) Inflation expectations do not respond to inflation after a real oil price shock (indirect channel of second round effect).