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Inflation Expectations and How it Explains the Inflationary Impact of Oil Price Shocks: Evidence from the Michigan Survey

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Analysis of the Michigan Survey data confirms U.S. inflation expectations are not perfectly anchored in the event of an oil price shock. Two key results emerge through counterfactual analysis. First, better anchoring of inflation expectations can ameliorate the mild inflation impact which occurs 10 to 12 months after an oil price shock. Second, an initial large burst of inflation from an oil price shock always occurs regardless whether inflation expectations are anchored or not. Therefore, while better anchoring of inflation expectations can lead to better inflation outcomes, these gains can be limited.

Keywords

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JEL Classification

C32, D84, E31

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Inflation Expectations and How it Explains the Inflationary Impact of Oil Price Shocks: Evidence from the Michigan Survey

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Abstract

Analysis of the Michigan Survey data confirms U.S. inflation expectations are not perfectly anchored in the event of an oil price shock. Two key results emerge through counterfactual analysis. First, better anchoring of inflation expectations can ameliorate the mild inflation impact which occurs 10 to 12 months after an oil price shock. Second, an initial large burst of inflation from an oil price shock always occurs regardless whether inflation expectations are anchored or not. Therefore, while better anchoring of inflation expectations can lead to better inflation outcomes, these gains can be limited.

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1 Introduction

There is considerable evidence to suggest that U.S. inflation expectations are positively correlated with oil prices.(e.g. Trehan, 2011; Beechey et al., 2011; Coibion and Gorodnichenko, 2012, 2014; Arora et al., 2013). A key accepted principle for the successful conduct of monetary policy is the ability to manage and anchor inflation expectations (see, e.g. Mishkin, 2007; Bernanke, 2007). It will then come as no surprise that we observe policymakers are indeed concerned with how to manage inflation expectations in the event of an oil price shock.[1] It has been suggested that oil price shocks may trigger for wage-price spirals by de-anchoring inflation expectations (e.g. Bernanke, 2007). This highlights inflation expectations, whether through price setting or wage bargaining mechanisms, as a possible channel where oil price shocks can feed into inflation. The premise of this argument relies on one main assumption. Namely, higher inflation expectations *will* always feed into higher realised inflation with causality in the inflation expectations-inflation relationship largely running in the direction from the former to the latter rather than vice versa. The degree of importance one should attach to the empirical relationship between inflation expectations and oil prices, at least for understanding inflation dynamics, thus rests on whether the mechanism supporting this main assumption is valid. Given this mechanism is largely assumed, rather than established, the current interpretation of the relevance of the oil price-inflation expectations relationship for understanding inflation dynamics is far from straightforward.

The contribution of this paper is to directly evaluate the aforementioned mechanism. I first estimate a Structural Vector Autoregression (SVAR) using a survey measure of inflation expectations. I then use the relationships uncovered from the estimated SVAR to generate counterfactuals to address the relevance of the relationship between oil prices and inflation expectations for understanding inflation dynamics. In particular, I consider counterfactuals where inflation expectations are anchored to varying degrees and investigate the differences in inflation dynamics arising from these counterfactual scenarios. Anchored inflation expectations is defined as inflation expectations remaining insensitive in the presence of macroeconomic shocks and fluctuations. In other words, if inflation expectations are perfectly anchored, they must necessarily be insensitive to *all* shocks and macroeconomic fluctuations. The intuition is that if anchoring inflation expectations matter for the transmission of oil price shocks into inflation, then we can expect the counterfactual inflation dynamics to differ from the ones estimated from the original SVAR. The counterfactuals will thus establish the relevance of inflation expectations for the propagation of oil price shocks into inflation.

[1] For example, quoting Federal Reserve Chairman Ben Bernanke in his semi annual report to Congress on 1 March 2011, *"sustained rises in the prices of oil or other commodities would represent a threat both to economic growth and to overall price stability, particularly if they were to cause inflation expectations to become less well anchored"*.

Methodologically, the paper is in line with a growing strand of literature which models survey data of expectations within a VAR framework (e.g. Barsky and Sims, 2012; Leduc and Sill, 2013). Within this strand, the paper relates most directly to work by Leduc et al. (2007) and Blanchard and Galí (2010), who investigate oil price shocks as possible triggers for inflation expectations and inflation in the 1970s. My contribution deviates from this body of work in two crucial dimensions. First, it is natural not to relegate the relationship between oil price shocks, inflation expectations and inflation as one that is just relevant for understanding the 1970s given one does anecdotally observe that the more recent oil price increases accompanied rising inflation expectations. Second, the contribution in this paper goes a step further by considering the importance of the role of inflation expectations in propagating oil price shocks by generating counterfactuals rather than relying directly on the estimated impulse response functions. As one expects inflation expectations and inflation will largely co-move in the same direction after an oil price shock, substantiating a claim that inflation expectations matter for the transmission of oil price shocks into actual inflation is not straightforward. Only by assuming that inflation expectations is the channel propagating inflation and largely dismissing the possibility of inflation expectations responding to inflation can one make this claim. The approach taken here directly addresses this claim since different counterfactuals can be used to assess these assumptions. The contribution in this paper can also provide further evidence on the debate regarding the "missing deflation" during the Great Recession. With extremely weak economic activity, the Great Recession was accompanied by high oil prices but extremely stable inflation. A prominent explanation is that inflation expectations are extremely well anchored, thus preventing deflation (Bernanke, 2010). An alternative view by Coibion and Gorodnichenko (2014) suggest because inflation expectations are *not* well anchored, heightened inflation expectations, possibly through high commodity prices, helped prop up inflation. These are contradictory views. Given this paper models inflation expectations, inflation and oil prices, providing evidence in reconciling these disparate views appears natural.

Using monthly data from the Michigan Survey from January 1978 to December 2013 as the measure of inflation expectations, the main results are as follows. There is evidence that oil price shocks do result in higher inflation and inflation expectations. This result confirms a long line of research which finds that U.S. inflation expectations are not fully anchored. Inflation dynamics in response to an oil price shock exhibits three bouts: an initial large burst on impact, and two milder lagged effect. Various counterfactuals of anchored inflation expectations suggest the lagged effect after 10 to 12 months can be mitigated, but not the initial large burst. Oil price shocks will permanently raise the CPI level. The eventual impact of an oil price shock on the price level in the various counterfactuals can range from being halved to no permanent effect depending on the degree of anchoring of inflation expectations.

The rest of the paper is organised as follows. Section 2 describes key features of the oil price, Michigan Survey inflation expectations and inflation data. Section 3 motivates the base model to first establish how oil price shocks impact inflation and inflation expectations. Section 4 presents the counterfactuals and evidence on the relevance of the role of inflation expectations in the transmission of oil price shocks into actual inflation. Section 5 addresses some specification issues and the final section concludes.

2 Data Properties

The analysis undertaken by this paper centres on three main time series, a survey measure of inflation expectations, a CPI inflation series and the real price of oil. A description of the model is provided in the next section, but it is worth first considering some of the time series properties of the data.

The measure of consumers' inflation expectations is from the Thomson Reuters/University of Michigan Survey of Consumers. This is colloquially referred to in the literature as the Michigan Survey. Every month, 500 households throughout the United States are surveyed with a variety of questions, with inflation expectations being one of them. To measure inflation expectations, the following question, A.12 on the questionnaire, is asked,

"During the next 12 months, do you think that prices in general will go up, or go down, or stay where they are now?"

If respondents answer they expect prices to go up or down, they will be asked the following (A.12b),

"By about what percent do you expect prices to go (up/down) on average, during the next 12 months?"

The answers to those questions provide a measure of household 12 month ahead inflation expectations.[2] The median measure from the survey is taken to quantify inflation expectations, as per the common approach.

The oil price series is the refiners acquisition price of imported crude. Given the U.S. is a net importer of crude oil, we can regard such a measure of the oil price as capturing the impact of developments in the oil market on the U.S. economy. The oil price is deflated using the U.S. CPI to obtain the real price of oil.[3] Inflation is measured using the U.S. CPI for urban consumers. The data coverage is from January 1978 to December 2013. This is the earliest possible starting date for the analysis given the data availability of the Michigan Survey.

Figure 1 plots the three time series. The well established stylised empirical relationship

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

[3]Kilian (2008) and Kilian (2009), *inter alia*, discuss why obtaining the real price of oil from the refiners acquisition of imported crude is the relevant measure for studying oil price shocks for the U.S.

between oil prices and inflation expectations is evident. We focus on four events in the oil market. One, the long decline of oil prices from the peak in 1981 after the second oil crisis, which culminated in the collapse of OPEC in 1986. Two, the Gulf War in late 1990 to early 1991, which resulted in a large jump in oil prices. Three, the general ascent of oil prices since 2000. Four, the global financial crisis in 2008, which temporarily punctuated this ascent. All four events are reflected looking at the inflation expectations data in the bottom left corner of Figure 1. A general fall in inflation expectations in the 1980s, a rise around the time of the 1990/91 Gulf War, slightly higher average inflation expectations post 2000, compared to the 1990s, and also the sharp temporary fall in 2008. Given the stylised relationship by eyeballing the data, it is not surprising that more formal econometric work is able to document this relationship. Comparing the inflation expectations data from the Michigan Survey and annualised month on month U.S. CPI inflation in the bottom two subplots suggests both time series largely co-move.[4]

Relevance of Inflation Expectations Measure

A natural question arises whether the Michigan Survey is an appropriate measure of inflation expectations. A key issue centres on the fact that the Michigan Survey is a household inflation survey while alternatives like the Survey of Professional Forecasters (SPF) survey industry professionals, and so should yield better forecasts. At a conceptual level, neither professional forecasters nor household inflation expectations should be more relevant than the other. Instead, it is firms' inflation expectations, which in turn influence their price setting decisions, that should be the conceptually relevant measure. Therefore, the issue of whether to use professional forecasters or household surveys is not a conceptual one. It is an issue of data availability because there does not exist firm level inflation expectations data for the U.S. The relevant consideration is thus whether either is a better proxy for firms' inflation expectations. The biggest perceived shortcoming about the Michigan Survey is the potential lack of sophistication among survey participants. However, this hypothesised lack of sophistication is not obvious from the empirical evidence in the literature. For example, Ang et al. (2007) show that the Michigan Survey provides good inflation forecasts. Coibion and Gorodnichenko (2014) also argue that about two thirds of firms in the United States are small and medium enterprises which are unlikely to be hiring a professional forecaster or paying for such forecasts. Therefore, firms' inflation expectations are more likely to be closer to that of household inflation expectations, a claim for which they proceed to provide empirical support for. There is thus no compelling evidence to suggest that the Michigan Survey should not be used for the empirical exercise,

[4] It appears inflation expectations is more persistent than inflation. This is a well known feature about inflation expectations survey data (see, e.g. Jain, 2013; Trehan, 2014), and is not limited to just the Michigan Survey. However, this is also partly an artefact of using month on month inflation. The difference in persistence in not important for the modelling choice.

with the possible case against it ambiguous, at best. From a practical perspective, the monthly frequency of the Michigan Survey yields a key advantage compared to commonly considered alternatives which are, at best, at quarterly frequencies (e.g. SPF, Livingstone Survey). The monthly data will yield sharper inferences through the larger number of observations. Moreover, the identification strategy relies on informational lags which rely explicitly on the monthly data frequency.

To circumvent concerns with the choice of inflation expectations series, SPF data is also considered with the obvious drawback for lower frequency data resulting in larger estimation imprecision. Largely similar conclusions to this paper can still be drawn rendering the case against the Michigan Survey data largely moot. We will revisit this point when discussing some sensitivity analysis in Section 5.

3 How Do Oil Price Shocks Impact Inflation Expectations and Inflation?

A natural starting point to investigate the link from oil price shocks to inflation and inflation expectations is to model all three variables in a trivariate system. 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 log of the real price of oil, the 12 month ahead inflation expectations from the Michigan survey formed at time t, and annualised month on month U.S. CPI inflation respectively. The A's are 3×3 coefficient matrices and ϵ_t is a 3×1 vector of orthogonal structural shocks, where $\mathbb{E}[\epsilon_t' \epsilon_t] = \Sigma$ and Σ is diagonal. The model is estimated with 12 lags owing to concerns about 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).

To identify the oil price shock, the oil price is identified as being pre-determined to the U.S. macroeconomy. This is consistent with empirical evidence by Kilian and Vega (2011) who show that the oil price is insensitive to U.S. macroeconomic news, at least at the monthly frequency. This amounts to restricting all the elements in the first row of the A_0 matrix to be zero apart from the (1,1), which is normalised to 1. The first shock in the system is interpreted as an oil price shock.[5] Fully identifying the system requires one

[5] 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 the approach by Kilian and Edelstein (2009), it is useful to view the exercise as estimating the average response to an oil price shock,

more restriction. At time t, current period inflation is not known due to lags in the release of macroeconomic data, but economic agents are free to form an expectation of future inflation. Therefore, 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 in the current period. This implies $A_{0,23} = 0$. This identifying restriction accounts for a mismatch in the timing when the inflation expectations survey is taken and release of macroeconomic data, and is quite commonly exploited in VARs using survey data. I thus follow the convention used 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 regards this as a shock to the economic agents' relevant information sets used to form inflation expectations or forecast inflation. Some existing work which also recursively order survey data above economic variables interpret shocks associated with the survey expectations as possible news shocks (e.g., see 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, then the identified inflation expectations shocks may well reflect expectations of future economic conditions. Therefore, interpretation of the inflation expectations shock as a news shock can be easily accommodated within the modelling framework.[6] All the restrictions, in addition to normalising all the diagonal elements of A_0 to 1, amount to identification through a Cholesky decomposition or assuming a recursive ordering of the variables.

It is worth contrasting some of the modelling choices relative to related work. First, while single equation work with often static specifications are common in studying inflation expectations and oil price shocks (e.g. Beechey et al., 2011; Arora et al., 2013), the VAR structure explicitly allows a role for dynamics, as strongly suggested by the persistence uncovered through simply eyeballing of Figure 1. Second, oil prices are modelled as evolving endogenously, consistent with the current consensus in the literature (see, e.g. Barsky and Kilian, 2002; Kilian, 2008). This contrasts with single equation models which will implicitly assume oil prices are exogenous.[7]

The top three subplots of Figure 2 presents impulse response functions to a one standard deviation oil price shock. This corresponds to a 6.3% increase in the real oil price, as estimated from the data. The standard errors are generated using a recursive design wild

reflecting the composition of the underlying oil price shocks within the sample period.

[6]The news shock interpretation *cannot* be accommodated if one chooses to order inflation above inflation expectations in a recursive identification scheme unless one assumes economic agents do not act on news immediately. This alternative ordering also ignores the timing of the survey and lags in data releases which has been explicitly exploited in the identification, yielding an economic model lacking in natural economic interpretation.

[7]Another common practice is to consider nonlinear transformations of the oil price as being exogenous (e.g. Hamilton, 2003). As shown by Kilian and Vigfusson (2011), nonlinear modelling of this type, if done correctly, is not a trivial endeavour. Given the goal of this paper, it appears more sensible to firstly establish the modelling framework in a linear framework before potentially considering a role for nonlinear extension such as the one described, if applicable.

bootstrap suggested by Gonçalves and Kilian (2004).[8] The dynamics of both inflation expectations and inflation have broad similarities. Following an initial rise, the peak responses occurs after one or two months, before a general decline. The peak responses also coincide with the peak response of the real oil price, further confirming the link between the three time series.

Inflation respond to oil price shocks in three spurts. An initial burst on impact, and milder lagged effects after 10 to 12 months and about 22 months respectively. Both Barsky and Kilian (2002) and Blinder and Rudd (2012) argue that after an oil price shock, if inflation expectations are well anchored, we should observe only a one off increase in inflation. This is nominally termed a first round effect. If inflation expectations become de-anchored, second round effects, for example through the wage-price spiral mechanism described by Bernanke (2007), are possible. These predictions are consistent with the estimated inflation dynamics after an oil price shock. While one cannot conclusively attribute the lagged increase after 10 to 12 and 22 months respectively as second round effects caused by de-anchored inflation expectations on the basis of these results, the evidence presented is consistent with that possibility. These lagged effects are statistically different from zero. Note the estimated response of inflation at all other horizon, apart from those highlighted are not statistically different from zero. This implies one does not observe sustained inflation from oil price shocks, but instead three separate inflationary bursts of varying degrees.

The real oil price remains persistently high after an oil price shock. This serves to highlight the point that oil price shocks are not one off increases in oil prices, as oil prices remain high for a long horizon. The persistence reaffirms the benefits of using a dynamic system to model these relationships rather than specifying static models. Inflation expectations also appear to remain persistently high after an oil price shock. This impact is statistically significant even after 20 months. The response of inflation expectations confirms vast evidence (e.g. Gürkaynak et al., 2005, 2010; Coibion and Gorodnichenko, 2014) that U.S. inflation expectations are not well anchored since the model implies they will be sensitive to movements in either oil prices, actual inflation or both. At this stage, it is still unclear whether these heightened inflation expectations serve as a channel to higher realised inflation. This is taken up in the next section of the paper.

Another way to study how important oil price shocks are to inflation expectations is through using historical decompositions. The bottom subplot of Figure 2 presents the historical decomposition for the inflation expectations series. It is striking that the historical decomposition for inflation expectations mirrors the real oil price series in Figure 1. The historical decomposition confirms the role oil price shocks have on inflation expectations.

[8] Baumeister and Peersman (2013a) present evidence of possible time-varying volatilities within the oil market, implying some form of conditional heteroskedasticity. This suggests a suitable application for the wild bootstrap.

It is reasonably clear that events associated with obvious oil price shocks in the data have a large role in driving inflation expectations. For example, from the collapse of OPEC in 1986 till the end of a general decline of oil price in 2000, oil price shocks drove the inflation expectations series below its baseline projection. The Gulf War of 1991 and oil price shocks of the 2000s similarly drove up inflation expectations.

These base results have various features which are consistent with a large class of empirical studies, despite differences in model specifications. Some of these features are the large initial inflation bout (e.g. Leduc et al., 2007; Blanchard and Galí, 2010; Kilian and Lewis, 2011), and increases in inflation expectations after an oil price shock (e.g. Leduc et al., 2007; Blanchard and Galí, 2010). In addition, there is also consistent evidence regarding the excess sensitivity of inflation expectations to oil price fluctuations (e.g. Trehan, 2011; Arora et al., 2013; Coibion and Gorodnichenko, 2014). The consistency of the results from the base model thus establish the ground to take the analysis from the model a step further to conduct counterfactual analysis.

4 Do Inflation Expectations Propagate the Impact of Oil Price Shocks?

The results in the previous section suggest inflation expectations and inflation both respond to oil price shocks. The previous analysis also establishes that U.S. inflation expectations are not well anchored and confirms well known evidence by, *inter alia*, Beechey et al. (2011) and Gürkaynak et al. (2005, 2010). While this aids in framing the discussion, it is not clear whether inflation expectations are merely responding to inflation or vice versa. In particular, are oil price shocks inflationary because inflation expectations are responding to oil price shocks, or are inflation expectations an irrelevant factor in the transmission of oil price shocks? In this section, this question is addressed through the use of suitable counterfactuals.

4.1 Constructing Counterfactual Impulse Response Functions

I consider three counterfactuals to study the problems. One of the counterfactuals considers fully anchored inflation expectations while the other two allows for some form of possible partial anchoring. These counterfactuals will yield counterfactual inflation dynamics. The intuition is as follows. If the anchoring of inflation expectations matter for inflation dynamics, then we can expect the counterfactual inflation dynamics to differ from the ones estimated previously. Analogously, if the counterfactual inflation dynamics do not differ substantially from those estimated in the previous section, then it is unclear whether the anchoring of inflation expectations conditional on oil price shocks is useful in influencing inflation outcomes. The approach of constructing counterfactuals to offset specific shocks and fluctuations has parallels to work by Sims and Zha (2006), Kilian and Lewis (2011) and Bachmann and Sims (2012).

Counterfactual 1: Fully Anchored Inflation Expectations

I first consider a case where inflation expectations are fully anchored. That is, inflation expectations are fully unresponsive to all shocks or fluctuations. To do so, I will construct a sequence of the identified inflation expectations shocks to offset the effect of all movements in inflation expectations along the entire impulse response function horizon. Recall these inflation expectations shocks are interpreted as shocks to the information set relevant in forming inflation expectations and can come in the form of news about the state of the general macroeconomy. To construct the counterfactual, first rewrite Equation (1),

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

where C has zeros on its diagonal and $C_{i,j} = -A_{0,ij}, i \neq j$. Define

$$\Lambda = \begin{pmatrix} C & A_1 & A_2 & \dots & A_p \end{pmatrix}.$$

The goal of the counterfactual is to offset the response of the second variable within the system, namely inflation expectations, through a constructed sequence of shocks to inflation expectations, which was identified previously. Denote the constructed sequence of inflation expectations shocks, $\epsilon_h^{\pi^e}, h \in \{0, 1, 2 \dots\}$. This sequence can be calculated through

$$\epsilon_h^{\pi^e} = -\sum_{j=1}^{K} \Lambda_{2,j} \Psi_j^h - \sum_{m=1}^{min(p,h)} \sum_{j=1}^{K} \Lambda_{2,mK+j} z_j^{h-m}. \quad (2)$$

K represents the number of variables in the system, three in the exercise. Conditional on both an oil price shock at horizon 0 and the counterfactual path of shocks $\epsilon_j^{\pi^e}, j \in \{0, 1, \dots h-1\}$, Ψ_j^h is the responses of the j^{th} variable at horizon h. Analogously, z_j^h is the response of the j^{th} variable at horizon h conditional on both an oil price shock at horizon 0 and the counterfactual path of shocks $\epsilon_j^{\pi^e}, j \in \{0, 1, \dots h\}$. Let ϵ_h be a vector of zeros except for the second elements set to $\epsilon_h^{\pi^e}$ as calculated in Equation (2), the sequence can be kicked off by first calculating

$$z_i^0 = \Psi_i^0 + \frac{e_i P \epsilon_0}{P_{2,2}}, i = 1, 2, 3 \quad (3)$$

where e_i is a selector vector with zeros except for the i^{th} element set to 1. P is the Cholesky factor of the covariance matrix of the reduced form VAR.[9] The rest of the

[9] A reduced form VAR, $y_t = \sum_{i=1}^{p} B_i y_{t-i} + \nu_t$ can be estimated through least squares. The estimated

sequence, $h \in \{1, 2, \ldots\}$, can be calculated recursively through

$$\Psi_i^h = \sum_{i>j} \Lambda_{i,j}\Psi_j^h + \sum_{m=1}^{min(p,h)} \sum_{j=1}^{K} \Lambda_{i,mK+j} z_j^{h-m}, i = 1, 2, 3 \quad (4)$$

$$z_i^h = \Psi_i^h + \frac{e_i P \epsilon_h}{P_{2,2}}, i = 1, 2, 3. \quad (5)$$

Counterfactual 2: Inflation Expectations are Insensitive to Oil Prices

Fully anchored inflation expectations can be a strong assumption. It is possible to construct counterfactuals under weaker conditions which rely on inflation expectations only being anchored to either to inflation or just the oil price fluctuations but leaves unconstrained the response to the other. These counterfactuals do not assume fully anchored inflation expectations, and allows for both partial and full anchoring. I first consider a counterfactual where inflation expectations are fully insensitive to fluctuations in the real oil price. To construct this counterfactual requires offsetting the response from the contemporaneous and lagged effect of the real oil price on inflation expectations (see Kilian and Lewis, 2011).

The ideas behind this counterfactual are twofold. First, if inflation expectations are indeed well anchored, except with respect to oil prices, then we can expect the counterfactual inflation expectations in this case to no longer be responsive. Second, if inflation dynamics do differ substantially if inflation expectations are insensitive to oil price shocks, then one cannot entirely rule out policy which may influence inflation expectations in the event of oil price shocks. For example, if it is indeed true inflation expectations are formed though regular interaction at the gas station or energy bills, there is possible merit to controlling gas and energy prices faced by consumers and firms to insulate them from forming inflation expectations on the basis of seeing their fuel and energy cost rise.

This alternative counterfactual sequence of shocks can be constructed through

$$\epsilon_h^{\pi^e} = -\Lambda_{2,1}\Psi_1^h - \sum_{m=1}^{min(p,h)} \Lambda_{2,mK+1} z_1^{h-m}. \quad (6)$$

The rest of the sequence can be similarly constructed using Equations (3) to (5) as defined previously.

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covariance matrix is $\mathbb{E}(\nu_t'\nu_t) = \Omega$. P can be obtained as a Cholesky factor of Ω where $\Omega = PP'$ and P is lower triangular. A response to a one standard deviation j^{th} shock is $\Psi_i^0 = P_{i,j}$. A suitable scaling of P can be used to consider alternative magnitudes of shocks.

Counterfactual 3: Inflation Expectations are Anchored to the General Macroeconomy

For the third counterfactual, I consider a case where inflation expectations are well anchored, except with respect to oil prices. This counterfactual allows inflation expectations to respond to fluctuations in the real oil price, but not inflation, or the general macroeconomy by extension. This counterfactual is a reversal of the one presented in Counterfactual 2 and is once again a weaker version of Counterfactual 1.

The idea behind this counterfactual is as follows. Suppose one accepts that inflation expectations will always be sensitive to oil price movements, whether through the constant visibility or interaction with oil prices. If this is indeed the case, will well anchored inflation expectations with the exception for oil prices still matter for inflation outcomes?

The shocks is this counterfactual can be computed through

$$\epsilon_h^{\pi^e} = -\Lambda_{2,3}\Psi_3^h - \sum_{m=1}^{min(p,h)} \Lambda_{2,mK+3} z_3^{h-m}. \tag{7}$$

The rest of the sequence can once again be constructed using Equations (3) to (5).

4.2 Counterfactual Results

Figure 3 presents the counterfactual impulse response functions. The solid line and shaded areas represent the point estimates and confidence bands of the original impulse response function estimated in Figure 2. The dotted line represents the various counterfactuals motivated previously. To gain an idea of the overall impact of oil price shocks on the price level, the rightmost subplots present the cumulative (non-annualised) log differences from the inflation impulse response functions in order to study the overall impact on the CPI level.

We first focus on the top row, where inflation expectations are fully anchored. In the leftmost subplot, the counterfactual for inflation expectations are held flat by construction in the counterfactual. The middle subplot presents the original inflation responses with its associated counterfactual. Strikingly, an initial burst of inflation in response to an oil price shock will occur whether or not inflation expectations are sensitive to oil price shocks. The counterfactual for inflation does suggests inflation falls marginally quicker after the initial burst of inflation if inflation expectations are held fixed. The lagged inflation response estimated about 10 to 12 months after the oil price shock, which suggests some possibility of a second round effect from oil price shocks in the original estimate, is no longer present in the counterfactual. The results suggest inflation expectations may be a significant channel in propagating the transmission of the lagged effect of oil price shocks into inflation. Note the third, yet milder, burst of inflation after around 22 months, is still present whether inflation expectations are fully anchored or not. The results are reflective of the previously mentioned argument by Barsky and Kilian (2002), and then, Blinder and Rudd (2012). An oil price shock should only see a one off increase in inflation if inflation expectations are well anchored. While not perfect, these predictions are somewhat borne out in the counterfactual given the lagged burst of inflation after around 10 to 12 months is mitigated by anchored inflation expectations. The rightmost subplot presents the overall impact on the CPI level. While an oil price shock will permanently raise the price level, the effect is transitory on the CPI in the counterfactual of perfectly anchored inflation expectations. These results suggest a possible role where perfectly anchored inflation expectations can improve inflation outcomes in the event of an oil price shock.

We now focus on the counterfactuals allowing for the possibility for inflation expectations to be partially anchored. The middle and bottom rows of Figure 3 depicts the counterfactuals where inflation expectations do not respond directly to the real oil price and inflation respectively. A few observations stand out.

First, the results offers further confirmation that inflation expectations in the U.S. are not perfectly anchored. In the case where inflation expectations do not respond to oil prices, inflation expectations are still sensitive to inflation. This heightened inflation expectations is evident even between the four to nine months after the shock, though inflation is not statistically different from zero at these horizons.[10] In the counterfactual where inflation expectations do not respond to inflation, inflation expectations are heightened for about three months, though it falls much faster. This is not surprising given it has been well established, not just previously but in various studies cited throughout this paper, that oil price shocks are an important driver of inflation expectations. Even so, both counterfactuals depict paths of inflation expectations which are milder compared to the original impulse response function, offering evidence that inflation expectations do have a role in propagating the inflationary impact of oil price shocks. It is also useful to note inflation expectations still rise in Counterfactual 2, even if they cannot respond to oil price shocks, which suggests an element of causality from inflation to inflation expectations. This reverse causality suggest one cannot automatically assume higher inflation expectations will feed into higher inflation upon observing positive co-movement in inflation expectations and inflation since the possibility of reverse causality cannot be dismissed.

Second, the counterfactual inflation dynamics in the partially anchored cases appear similar to the counterfactual under fully anchored inflation expectations. The major exception centres on the response during the second burst of inflation 10 to 12 months after the oil price shock. Under fully anchored inflation expectations, inflation is fully mitigated during the second burst, while they are only somewhat mitigated under both the two alternative counterfactuals, though still statistically different from the original

[10]The zero response of inflation expectations on impact is due to the Cholesky decomposition since all movements in inflation expectations on the impact horizon is due to oil price by construction.

response.

Third, the final impact on the CPI price level is still statistically different from the original estimate under the two alternative counterfactuals. Nevertheless, while the counterfactual of fully anchored inflation expectations suggests the effect of an oil price shock to be transitory, it is still permanent for the two alternative counterfactuals. The final impact on the price level though is approximately halved under the two alternative counterfactuals.

A useful exercise is to compute the ratio of the forecast variances between the various counterfactuals and the originally estimated impulse response function conditional on an oil price shock. Denoting χ_i^h as the ratio between the forecast variance of the i^{th} variable in the counterfactual relative to the original impulse response function,

$$\chi_i^h = \frac{\sum_{k=0}^{h}(C_j^k)^2}{\sum_{k=0}^{h}(\Theta_i^k)^2}, j = 1, 2, 3 \tag{8}$$

where C_1^k, C_2^k and C_3^k represents Counterfactual 1, 2 or 3 as motivated earlier which coincide respectively with the analogous series of z_i^k associated with those counterfactuals. Θ_i^k represents the original impulse response function for the i^{th} variable to an oil price shock at horizon k.

The mean ratios of the counterfactual inflation forecast variance relative to the original response across all 33 horizons is about 70%, 75% and 90% for Counterfactuals 1, 2 and 3 respectively. Since the forecast variance for all three counterfactuals are smaller compared to the original estimated inflation response, some form of anchoring of inflation expectations does reduce inflation volatility in the event of an oil price shock. Even though some of these reduction in inflation volatility are non-trivial, they are not large. Studying the inflation dynamics in the counterfactual and originally estimated impulse response functions tells us why this variance reduction is modest. Most of the variability in inflation occurs with the initial burst when the oil price shock hits, a feature that is present in all three counterfactuals. With a reduction of inflation volatility of only about 10% for Counterfactual 3, the largest reduction in inflation volatility is through some form of anchoring of inflation expectations to fluctuations in oil prices. If the U.S. is able to perfectly anchor inflation expectations, the model estimates inflation volatility conditional on an oil price shock will fall by slightly over a quarter .

The results here are useful to bring into the policy discussion. In particular, policymakers talk about oil price shocks in their official capacity. The idea is to try shape, or anchor inflation expectations in the event of an oil price shock. The analysis in this paper indicates that there is room to improve inflation outcomes in the U.S. in the event of an oil price shock if inflation expectations are better anchored. This also reaffirms an assumed tenet that inflation expectations do act as a channel to propagate the inflationary impacts of oil price shocks. This also ties in with work by, for example Gürkaynak et al.

(2005, 2010) and Beechey et al. (2011), who suggest inflation expectations in the U.S. are not as well anchored as economies such as the Euro area, Sweden and the United Kingdom. Nevertheless, the degree of reduction in inflation variability conditional on an oil price shock through better anchoring of inflation expectations is modest. That is, while inflation outcomes after an oil price shock in the U.S. can be improved through better anchoring of inflation expectations, the room for better inflation outcomes is limited.

4.3 Can Oil Prices and Inflation Expectations Explain the Missing Deflation of the Great Recession?

If the relationships uncovered within the body of the paper are stable across the sample period with little time variation, can the evidence uncovered within this paper reconcile with the recent debate on the "missing deflation"? During the Great Recession, there was a sustained weakness in the U.S. economy, yet deflation did not occur. In fact, inflation was very stable. This period was also accompanied by very high oil prices, mainly driven by high commodities demand by emerging markets. Bernanke (2010) provides an explanation widely accepted within policy circles: inflation expectations are well anchored and therefore, deflation does not occur. At face value, this explanation is not plausible given this paper confirms a long line of empirical research which shows U.S. inflation expectations are anything but well anchored. High oil prices provide a natural alternative answer. For example, Gordon (2013) argues that supply shocks need to be modelled to understand inflation dynamics. To the extent that high oil prices represent supply shocks, this appears a plausible explanation. Coibion and Gorodnichenko (2014) argue high inflation expectations prevented deflation, tentatively arguing high oil prices are a possible prop for inflation expectations.

In order to assess these claims, I generate a counterfactual inflation series from January 2009 to December 2013, 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. In particular, I generate counterfactual inflation series for scenarios where the real oil price and inflation expectations stayed at the level they were at in January 2009.[11] Figure 4 presents the counterfactual inflation series. The main claim of Coibion and Gorodnichenko (2014) is supported. Heightened inflation expectations prevented deflation. If inflation expectations were well anchored, deflation would have ensued. There is, however, a certain nuance to this result because the counterfactual of anchored inflation expectations do

[11] In order to generate these counterfactual, I generate a sequence of structural shocks to the real oil price and inflation expectations to keep their paths flat for their respective counterfactuals. 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.

not immediately lend itself to the fact that it was oil prices which caused these high inflation expectations. This is clearly shown with the counterfactual keeping oil prices flat. Inflation dynamics 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 much from the actual path. Therefore, there only exists partial support for the position of higher oil prices preventing deflation.

How does one reconcile these explanation? It is possible oil price shocks only represented one type of commodity price shock. It is worth noting that there were many possible events which could have heightened inflation expectations, from high food prices to the perceived easy money of quantitative easing. Moreover, as previously estimated, most of the inflationary impact of oil price shocks are from the initial burst upon impact and generally decay within three months. Therefore, to generate a counterfactual where high oil prices prevents deflation requires a continuous sequence of very large, probably implausible, oil price shocks. In other words, for there to exist firm evidence that oil prices prevented deflation, oil prices have to be much higher than the levels they were at in 2009, and more so in 2010 and 2011. Given oil prices in 2010 and 2011 were at historically very high levels, this appears unlikely.

5 Sensitivity Analysis

The robustness of the analysis is tested on a number of dimensions. To conserve space, I discuss only two of the issues which the reader may be most concerned with.[12]

Using Great Moderation Data

There may be concerns that using a sample from 1978 includes the second oil crisis. While the results of Kilian and Lewis (2011) suggest a reasonably stable relationship in the oil inflation relationship pre and post Great Moderation, there is work suggesting that the relationship between oil prices and inflation and possibly inflation expectations could be time-varying on a number of dimensions (e.g. Kilian and Edelstein, 2009; Blanchard and Galí, 2010; Baumeister and Peersman, 2013a,b; Wong, 2013). A natural exercise is to consider a breakdate of 1986. This coincides with both the Great Moderation and the collapse of OPEC.

The impulse response function of inflation to an oil price shock and its associated counterfactual of perfectly anchored inflation expectations (i.e. Counterfactual 1) is presented as the two top subplots of Figure 5. These subplots present both annualised inflation and

[12]Robustness tests will be provided upon request. More routine minor concerns like lag length (it is robust up to 24 lags) and the specification of the oil price (e.g. nominal price, first differencing etc) are not an issue.

the cumulative (non-annualised) log difference in the price level. The results reassures the main analysis is not an artefact of the 1979/80 oil shock. The general conclusions, where perfectly anchored inflation expectations cannot prevent an initial burst of inflation, but can mitigate a milder lagged inflation effect about 10 to 12 months after the oil price shock, is evident. Given no evidence that the main conclusions of the paper are driven by any particular subsample, it is straightforward to prefer the base specification exploiting the full span of the Michigan survey data starting in 1978.

The results draw a contrast against the work of Mehra and Herrington (2008). In their study, oil shocks, modelled as quantitative dummies using Hamilton's (2003) nonlinear transformation of the oil price, have little effect on inflation expectations in a post 1979 sample. The evidence here indicates this view has to be balanced against the finding that there is little time variation in a linear case. Their approach will also need to be updated to account for work by Kilian and Vigfusson (2011) in order to evaluate the case of nonlinearity to contrast with the evidence presented here. The results here indicate as a starting point, that we cannot entirely dismiss the evidence from linear VARs of little time variation. In this respect, the results here are more consistent with the view by Kilian and Lewis (2011).

Survey of Professional Forecasters

As previously mentioned, there may be concerns about the Michigan Survey data. The robustness of the analysis is checked against using the Survey of Professional Forecasters. This is presented in the bottom two subplots of Figure 5, with annualised inflation and the cumulative log difference of the CPI. Once again, the counterfactual exercise is for inflation to be perfectly anchored. The larger variance of the impulse response functions given the lower frequency data has less observations is noticeable. Even so, the counterfactual of perfectly anchored inflation expectations produces an inflation response which is statistically significantly different from the original impulse response function, though very barely due to the large estimation variance. In particular, the second burst of inflation is mitigated by fully anchored inflation expectations. The differences are more obvious with the price level where there is a marked difference between the impact on the price level from 4 quarters onwards. Therefore, we can still draw the same conclusions as in the main body of the paper.

6 Conclusion

This paper evaluates the impact oil price shocks have on inflation expectations and how this subsequently impacts on inflation dynamics. The results indicate in counterfactuals where U.S. inflation expectations are anchored, inflation dynamics can be slightly altered.

In particular, a lagged inflation response 10 to 12 months after an oil price shocks does not occur in a counterfactual if inflation expectations are perfectly anchored. This strongly suggest inflation expectations do propagate oil price shocks in the U.S. Even so, anchored inflation expectations cannot mitigate the initial burst of inflation of an oil price shock. Therefore, while better inflation outcomes in the U.S. emerge after an oil price shock if inflation expectations are better anchored, there are limits to what anchored inflation expectations can achieve.

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Figure 1: Time Series Plots

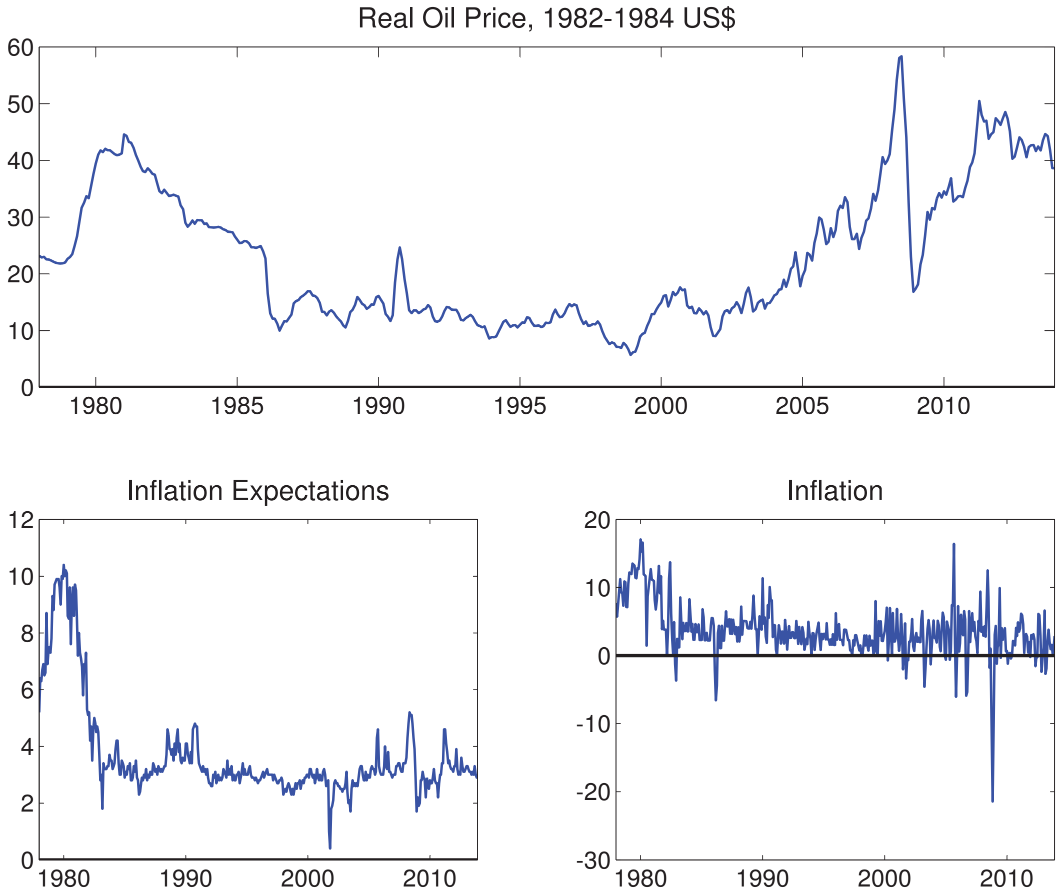
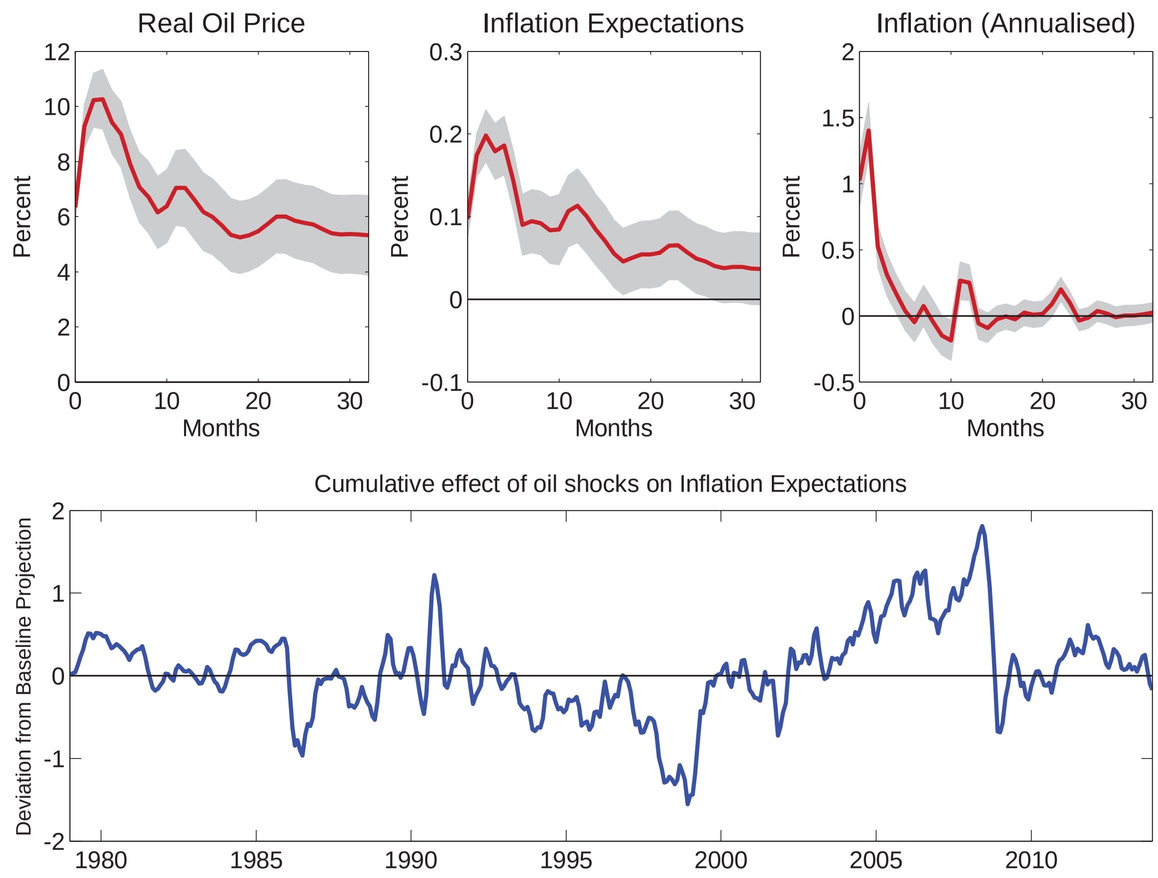
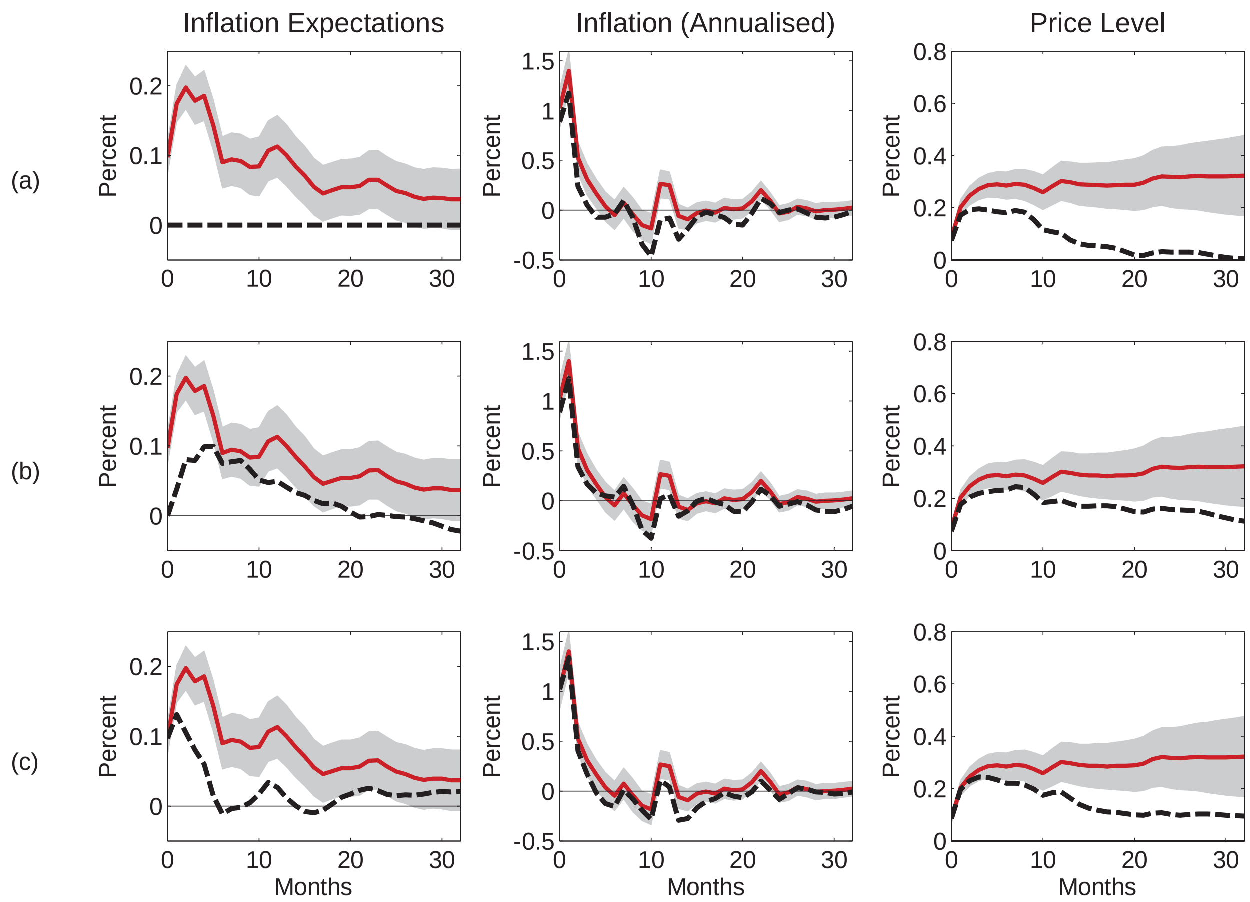


Figure 2: Impact of Oil Price Shocks



Notes: Top three subplots are the impulse response functions to a one standard deviation oil price shock. This coincides with a 6.3% increase in the real oil price upon impact from the model estimated on the data sample. Shaded areas represent one standard deviation error bands computed using the wild bootstrap proposed by Gonçalves and Kilian (2004).
The bottom subplot presents the cumulative effect of oil price shocks on inflation expectations through a historical decomposition.

Figure 3: Counterfactual Results



Notes: Counterfactuals shown in dashed lines. Original impulse response functions and error bands are presented as the solid line and shaded area respectively.

(a) Counterfactual 1: Fully anchored inflation expectations.

(b) Counterfactual 2: Inflation expectations do not respond directly to the real oil price.

(c) Counterfactual 3: Inflation expectations do not respond directly to inflation.

Figure 4: Great Recession Counterfactual, Annualised Monthly Inflation

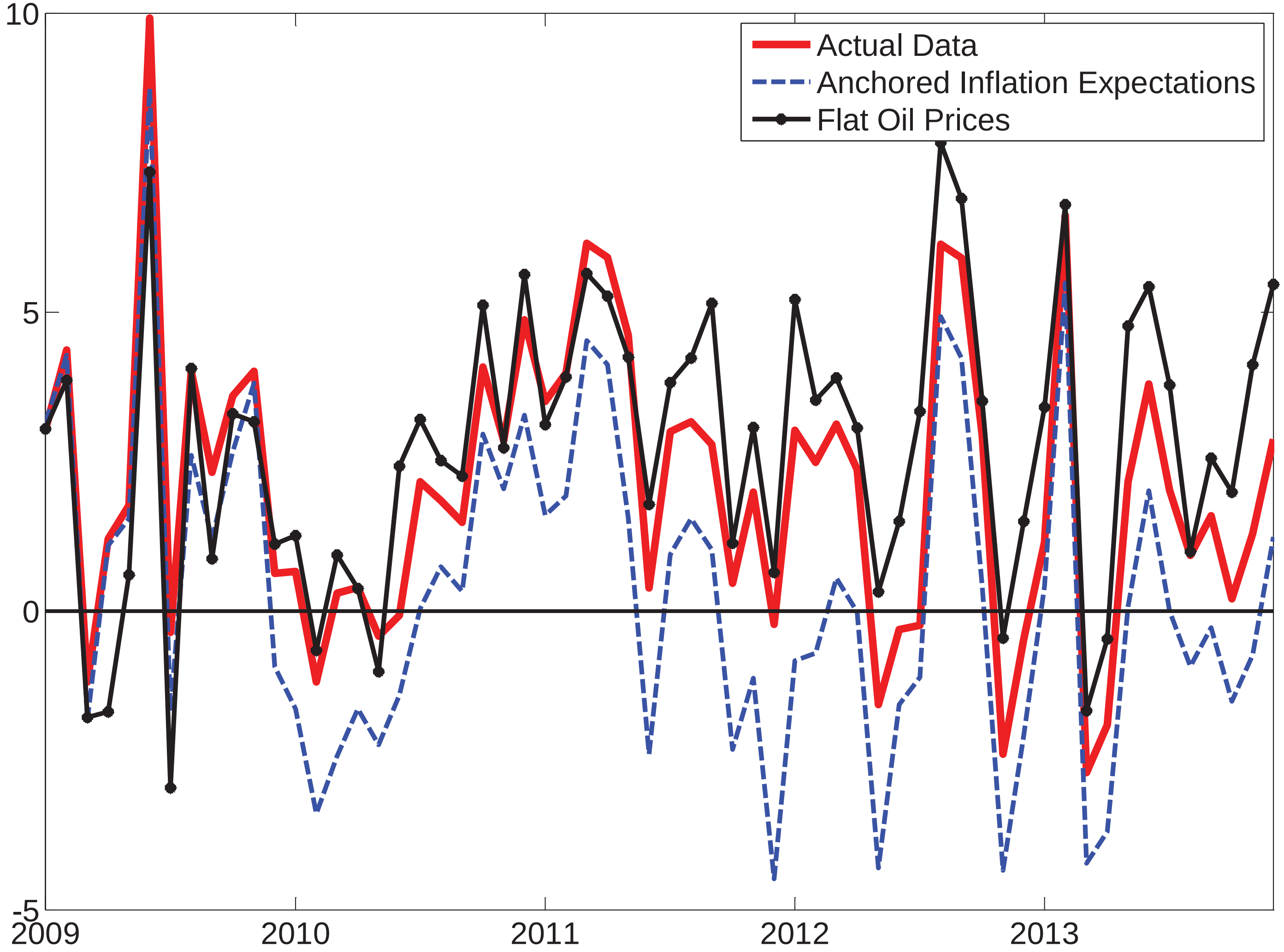
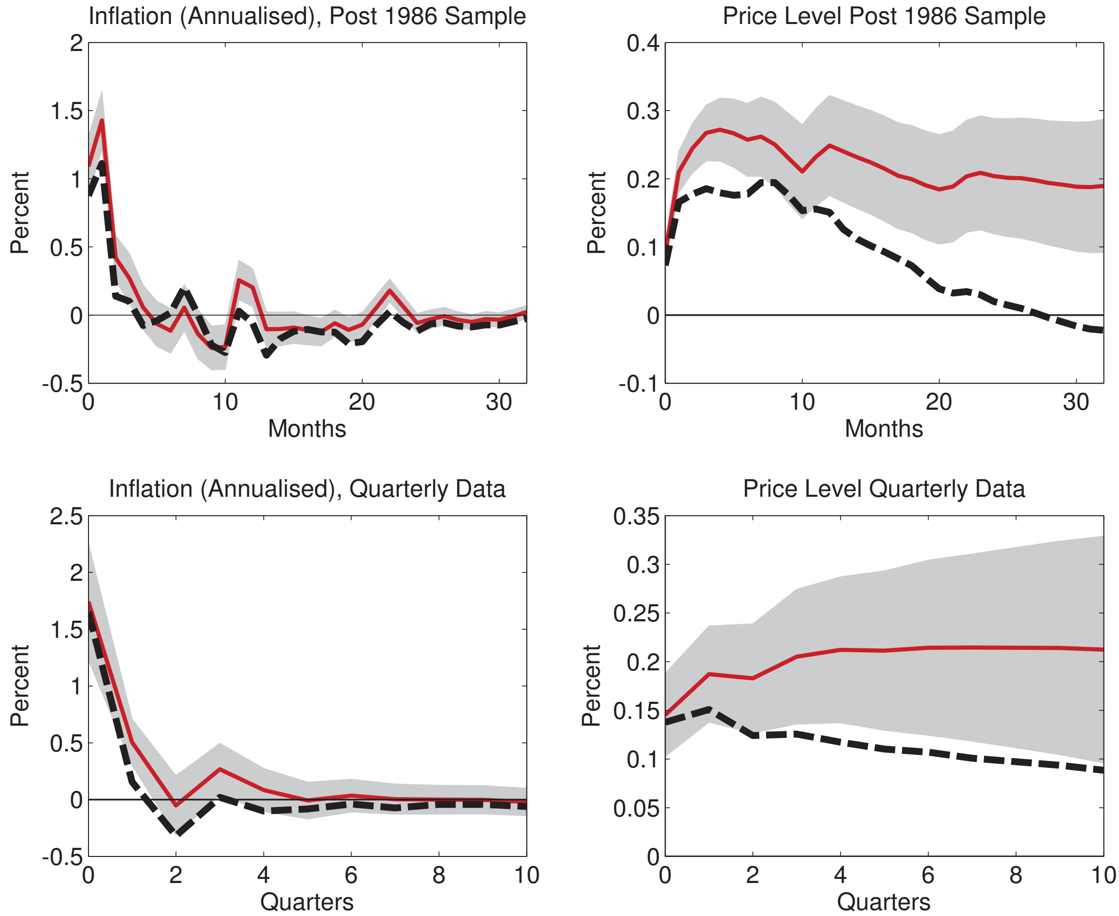


Figure 5: Counterfactual Impulse Response Functions Assuming Perfect Anchoring of Inflation Expectations, Alternative Specifications



The top row presents the same exercise as the main body of the paper with a truncated sample starting in 1986. The bottom row presents the same exercise as the main body of the paper using quarterly data from the Survey of Professional Forecasters.
Solid lines represents actual impulse response function. Shaded areas represent one standard deviation error bands computed using the wild bootstrap proposed by Gonçalves and Kilian (2004). Dotted lines represents the counterfactual holding inflation expectations fixed.