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Abstract

Despite growing interest in the impact of oil and other energy price shocks on inflation and inflation expectations, until recently this question has not received much attention. This survey not only presents empirical results for the U.S. economy, but expands the analysis to include other major economies. We find that only in the Euro area and in the U.K. energy price shocks are associated with a material increase in core consumer prices. This helps explain the somewhat more persistent response of headline inflation in these countries than in the U.S. or Canada. Inflation is even less sensitive to energy price shocks in Japan. We document that energy price shocks played a more important role in explaining headline inflation in the Euro area in 2021 and 2022 than in the U.S. This does not mean that energy price shocks have de-anchored inflation expectations, however. While suitable data on long-run inflation expectations are scant, neither for the U.S. nor the U.K. is there evidence that energy price shocks have materially changed long-run inflation expectations.

JEL code: E31, Q43

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1. Introduction

Interest in the link between oil prices and inflation dates back to the 1970s and early 1980s, which saw two unprecedented surges in the price of oil and persistently high consumer price inflation. A natural conjecture at the time was that this sustained inflation occurred in response to sharp increases in the price of oil, given that neither phenomenon had any precedent in postwar history (e.g., Blinder 1982). Implicitly, this view was based on the premise that the price of oil is determined by geopolitical events that are exogenous with respect to U.S. inflation. Subsequently, this premise has been shown to be implausible. Neither direct evidence nor estimates of structural models that allow for both demand and supply shifts in global oil markets support the view that oil price fluctuations are primarily driven by exogenous oil supply shocks (e.g., Kilian 2008a; Kilian 2009a; Kilian and Murphy 2014; Kilian and Zhou 2022a).

An alternative explanation first proposed by Barsky and Kilian (2002, 2004) and summarized in Kilian (2010) is that worldwide shifts in monetary policy regimes not related to the oil market played a major role in causing both the major oil price increases of the 1970s and the high inflation in many OECD economies. In this view, the oil price increases in 1972-74 and 1979-80 mainly reflected surges in global demand for industrial commodities ultimately caused by expansionary monetary policy. In other words, rising oil prices were a symptom rather than the cause of high U.S. inflation.

Not only did U.S. inflation share a common demand component with oil prices, but higher U.S. inflation directly motivated increases in the price of oil in 1973/74, as OPEC oil producers saw their real earnings erode. Barsky and Kilian provide evidence that much of the surge in inflation in the early 1970s predated the surge in the price of oil, given the regulatory and contractual constraints on the price of oil at the time. This evidence is also consistent with estimates of conventional structural VAR models of the global oil market. Kilian (2009b) shows that much of U.S. inflation in the late 1970s and early 1980s can be explained by global demand shifts that also drove the price of crude oil.

From an econometric point of view this means that we need to allow for potential lagged feedback from inflation to the price of oil (and its derivatives such as the price of gasoline) in assessing the inflationary impact of higher oil prices. It also means that an oil price shock may capture broader shifts in global demand resulting in higher inflationary pressures than an increase in the price of oil, all else equal, would. Section 2 discusses the effects of the latter type of shock on consumer price inflation. We stress that the price of oil does not enter the consumer basket directly, but is reflected first and foremost in the prices of gasoline, diesel and jet fuel, which are transmitted through a number of different channels. We also highlight the response of inflation expectations and the potential emergence of a wage-price spiral. In Section 3, we quantify the responses of U.S. headline and core inflation to gasoline price shocks. Section 4 discusses the corresponding responses of household inflation expectations and a broader measure of U.S. inflation expectations developed by the Cleveland Fed. Sections 5 and 6 extend this analysis to other major economies focusing on broader measures of energy price shocks. The concluding remarks are in Section 7.

2. Why Oil Prices Matter for Inflation

Crude oil is not part of the basket of goods purchased by consumers, but unexpected changes in the price of oil may affect a range of consumer prices both directly and indirectly. Most importantly, the price of refined products such as gasoline, diesel, jet fuel, or heating oil directly depends on the cost of crude oil acquired by refiners.

Of these products only gasoline is directly consumed by most U.S. households. Gasoline expenditures account for 3% of all household expenditures. Given that the cost share of crude oil in the retail price of gasoline is about one half, a rough rule of thumb is that a 20% unexpected increase in the price of crude oil translates to a 10% increase in the consumer price of gasoline, which is expected to raise the CPI by 0.3%, all else equal. Since the full passthrough from an increase in the price of oil to the price of gasoline takes only about four weeks, oil price shocks tend to have an immediate effect on the monthly consumer price index (CPI) and the price index for personal consumption expenditures (PCE) (see, e.g., Chudik and Georgiadis 2022).

In contrast, increases in the price of jet fuel matter for consumer prices only indirectly to the extent that they raise airfares for personal travel or that higher costs of air cargo and business travel are being passed on by producers to other consumer prices. These indirect effects tend to be smaller and may be delayed. Similarly, except for the small share of households that rely on heating oil for home heating, increases in the prices of diesel fuel and heating oil in the United States affect most households only indirectly, as producers of other goods and services raise their prices to compensate for rising fuel costs.[1]

These effects on consumer prices may compound over time, as rising fuel costs are gradually absorbed by the economy. However, much depends on the ability of producers to pass on cost increases to consumers. For example, farmers in the United States purchase diesel fuel to run agricultural machinery, but tend to lack the ability to pass on higher diesel fuel costs, given the market power of the intermediaries purchasing corn and wheat. In contrast, 70% of energy price-driven changes in the input costs of manufacturing firms are passed through to consumers in the short to medium run (see Ganapati, Shapiro and Walker 2020). Thus, the extent and timing of the passthrough from fuel price shocks to inflation is an empirical question.

[1] In Europe it is more common for diesel fuel to be consumed directly than in the United States with 52% of all new cars registered in the EU in 2015 having diesel engines. Even in 2019, this share remained at 32%.

Under normal circumstances, one would expect a one-time permanent unexpected increase in the oil price to raise the level of consumer prices permanently, while increasing inflation only temporarily. One reason many economists are concerned that oil price shocks may trigger persistent inflation is the response of nominal wages to the consumer price increases caused by oil price shocks. Just as firms may seek to raise their product prices to compensate for rising fuel costs, workers may seek to raise their nominal wage to compensate for rising consumer prices. This process may prevent the real wage from falling enough to reflect the increased scarcity of oil, creating unemployment. In the limit, as the real wage remains unchanged, there will be perpetual inflationary pressures.

Blanchard (1986) coined the term wage-price spiral to refer to the process of repeated adjustments of nominal prices and nominal wages that results from attempts by workers to maintain their real wage and by firms to maintain their markup of prices over wages. Such a spiral could start from attempts by workers to maintain the same real wage in the face of an adverse oil price shock, causing persistent inflationary pressures, especially as higher inflation becomes embedded in inflation expectations.[2]

A wage-price spiral requires workers to have sufficient bargaining power to offset consumer price inflation, which is why wage-price spirals are most likely to emerge in countries with strong trade unions such as the U.K. in the 1970s. This explanation has never been particularly compelling for the United States, even granting that unions and collective bargaining agreements in the 1970s may have slowed the decline in U.S. real wages in response to oil price shocks. Alternatively, a persistent shortage of workers may also be conducive to the emergence of a wage-price spiral because it raises workers' bargaining power.

[2] For an alternative theoretical treatment of wage-price spirals see Lorenzoni and Werning (2023).

Although there is little concrete evidence of wage-price spirals, defined as a persistent acceleration of prices and wages, in historical data, as documented in Alvarez et al. (2022), this idea has played an outsized role in policy debates since the 1980s. Central bankers are concerned not only with the response of consumer price inflation to oil price shocks, but more generally also with the response of inflation expectations. While it is not surprising for short-run inflation expectations to increase in the wake of an oil price shock, the central question is whether longer-run inflation expectations respond. A lack of trust in the central bank's ability to maintain its long-run inflation target, in particular, would be reflected in rising long-term inflation expectations and such a de-anchoring of inflation expectations would be conducive to the emergence of a wage-price spiral.

3. U.S. inflation Responses to Gasoline Price Shocks

The standard tool for estimating the impact of oil price shocks on the macroeconomy has been block recursive VAR models (or equivalent local projections) that impose the identifying assumption that oil price shocks are predetermined with respect to macroeconomic aggregates (see Kilian and Vega 2011). Examples of such studies include Bernanke, Gertler and Watson (1997), Clark and Terry (2010), Kilian and Lewis (2011), Wong (2015), and Conflitti and Luciani (2019).

This approach, however, ignores the fact that the prices of refined products such as gasoline and diesel fuel do not necessarily move proportionately with percent changes in the price of oil. Crude oil is only one cost component in producing refined products. The price of gasoline, for example, also depends on the costs of refining, marketing and distribution as well as gasoline taxes that are all subject to time variation. Recent research instead has focused on gasoline price shocks because of their direct impact on consumer prices and because of their perceived salience to consumers, which makes it more likely that inflation expectations would respond to gasoline price shocks. As shown in Kilian and Zhou (2022b), replacing the price of oil in a VAR model of inflation with the price of gasoline may substantially affect the responses of inflation and inflation expectations, indicating that this distinction is important.

In this section, we examine the inflationary impact of gasoline price shocks in the United States from April 1990, when monthly data for long-term household inflation expectations first became available from the Michigan Survey of Consumers, to June 2023. Let $y_t = [\Delta pgas_t, \pi_t, \pi_t^{core}, \pi_t^{1-yr\,\exp}, \pi_t^{5-yr\,\exp}]'$, where $\Delta pgas_t$ denotes the growth rate of the CPI for gasoline (all grades). Unlike in Europe, few consumers in the United States buy diesel fuel, so the price of gasoline largely captures the price of motor fuel in the CPI. π_t denotes the headline CPI inflation rate and π_t^{core} the CPI inflation rate excluding food and energy (a common measure of the core inflation rate). Including both headline and core inflation measures helps separate the broader inflationary impact of gasoline price shocks from their impact on headline inflation. The model also includes both short-run and long-run household inflation expectations data given the importance of these expectations for the debate about the possible emergence of a wage-price spiral (see Section 2). $\pi_t^{1-yr\,\exp}$ and $\pi_t^{5-yr\,\exp}$ denote the Michigan Survey of Consumers' measure of the median household expectation of inflation over the next year and the next five years, respectively.[3] All data have been seasonally adjusted.

We postulate that these data are jointly explained by a VAR(6) model with an intercept.

[3] The use of household survey data makes sense in this context because household expectations are widely viewed as a more appropriate indicator of the inflation expectations of businesses than alternative measures of inflation expectations such as professional inflation forecasts, making them the best overall measure of inflation expectations in the economy (e.g., Coibion and Gorodnichenko 2015). In addition, the Michigan survey data provide a consistent measure of expectations for the short and the long run, with the 5-year expectation measuring inflation expectations at a longer horizon than alternative household data sources. Finally, they are available at monthly rather than just quarterly frequency and for a sufficiently long period.

The model is partially identified in that only the gasoline price shock is identified based on the assumption that the nominal price of gasoline is predetermined with respect to the other model variables. This assumption is supported by empirical evidence in Kilian and Vega (2011). The responses to the nominal gasoline price shock are invariant to the identification of the remaining structural shocks. The vector of structural shocks, w_t, is linked to the vector of reduced-form VAR errors, u_t, by the structural impact multiplier matrix B_0^{-1}. Under our identifying assumptions,

$$\begin{pmatrix} u_t^{\Delta pgas} \\ u_t^{\pi^{CPI}} \\ u_t^{\pi^{CPI,core}} \\ u_t^{\pi^{1-yr\ \exp}} \\ u_t^{\pi^{5-yr\ \exp}} \end{pmatrix} = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & * & * & * \\ * & * & * & * & * \\ * & * & * & * & * \\ * & * & * & * & * \end{bmatrix} \begin{pmatrix} w_t^{\text{nominal gasoline price}} \\ w_t^2 \\ w_t^3 \\ w_t^4 \\ w_t^5 \end{pmatrix}, \tag{1}$$

where $*$ denotes elements of B_0^{-1} that remain unrestricted. The model is estimated by Bayesian methods using a diffuse Gaussian prior for the slope parameters centered on zero and an inverse Wishart prior. All results are based on 5,000 posterior draws. The Bayes estimate of the vector of impulse responses is constructed under additively separable absolute loss, as discussed in Inoue and Kilian (2022), as are the approximations to the 68% joint credible set for this vector.

Figure 1 shows the impulse response function of monthly headline inflation (expressed at annualized rates) to a 10% nominal gasoline price shock. The response is immediate, but dies out quickly. There is no indication of large secondary effects of the shock. The response of core inflation is positive, but indistinguishable from zero based on the joint 68% credible sets. Table 1 shows that gasoline price shocks explain 69% of the variation in monthly headline inflation rates, but only 9% of the variation in monthly core inflation rates, consistent with the muted response of core inflation.[4]

An important question for policymakers is how much gasoline price shocks added to inflation and inflation expectations during 2020-2023, when the U.S. gasoline price underwent substantial fluctuations. This question may be addressed by constructing the counterfactual of how inflation would have evolved in the absence of gasoline price shocks (see Kilian and Lütkepohl 2017). Figure 2 shows that gasoline price shocks explain well the decline in headline inflation in early 2020, when the economy contracted. They also help understand the recovery in early 2021 and the inflation surge after the invasion of Ukraine in 2022, but the bulk of the headline inflation since 2021 has not associated with gasoline price shocks. Moreover, core inflation remained largely unaffected by gasoline price shocks.

Our results are robust to alternative identifying strategies, model specifications, lag order choices and price measures and are consistent with other recent estimates reported in the literature (e.g., Kilian and Zhou 2022b,c; Kilian and Zhou 2023; Blanchard and Bernanke 2023).[5] They indicate that there is no evidence that positive gasoline price shocks cause persistent increases in inflation. In related work, it has been suggested that the response of inflation to oil price shocks (and hence gasoline price shocks) was much more persistent in the 1970s and early 1980s than today (e.g., Blanchard and Bernanke 2023; Blanchard and Gali 2009; Blanchard and Riggi 2013; Clark and Terry 2010). The empirical support for this view continues to be debated, however. For example, Leduc, Sill and Stark (2007) conclude that even the oil price shocks of the 1970s were not associated with long-lasting statistically significant increases in expected or actual inflation. Related work also includes Boschen and Weise (2003).

[4] There is no evidence that the estimates are sensitive to excluding data from the Covid-19 epidemic which may have changed the responses of inflation to energy price shocks, as consumers reduced their driving and flying, while increasingly relying on online orders and deliveries.
[5] For a diverging view see Gagliardone and Gertler (2023) who work with an estimated New Keynesian model.

Four main explanations for the reduced persistence of inflation responses have been advanced. One is that the U.S. economy has become less oil dependent. Results in Kilian and Zhou (2022b) using data starting in mid-1981, however, cast doubt on this conjecture. That study shows that working with expenditure share-weighted nominal gasoline price shocks does not change the responsiveness of inflation. Another explanation is that the response of monetary policymakers to oil price shocks has improved, but that explanation has been called into question by a number of studies (e.g., Kilian and Lewis 2011). The third explanation is that U.S. real wage rigidities have declined, but there is no evidence that this explanation holds in the data (e.g., Bachmeier and Cha 2011). An alternative explanation stressed by Kilian (2009a,b) is that the reduced persistence of inflation responses to oil price shocks may be explained by changes in the mix of oil demand and oil supply shocks.

How much the inflation responses to gasoline price shocks have changed since the 1970s may be examined using model (1) without the expectations variables that only extend back to early 1990. Figure 3 shows that the inflationary effects are much the same whether using data for 1974.1-2023.6 or for 1990.4-2023.6, indicating a stable relationship over time. There is some evidence that, prior to 1990, the response of headline inflation was smaller on impact and somewhat more persistent, but there is no indication of a protracted increase in inflation for one year, as suggested by some earlier studies based on oil price shocks. Figure 3 also shows that the response of core inflation was somewhat larger before 1990 (not unlike the responses for European countries shown in section 5), but none of these larger responses are distinguishable from zero. In addition, there is no evidence that the long-run effect of a gasoline price shock on the level of the headline CPI was much different before 1990 than after 1990. The main difference is greater uncertainty about these effects in the data before 1990.

4. Responses of U.S. Inflation Expectations to Gasoline Price Shocks

There is a large literature examining the impact of gasoline price shocks as well as oil price shocks on inflation expectations. Some of that literature relies on panel regressions for household-level data (e.g., Binder 2018; Binder and Madrikis 2022; Madeira and Zafar 2015). Other studies employ reduced-form time series regressions (e.g., Coibion and Gorodnichenko 2015; Conflitti and Cristadoro 2018), autoregressive distributed lag models (e.g., Hammoudeh and Reboredo 2018), or structural VAR models (e.g., Aastveit et al. 2023; Kilian and Zhou 2022b,c; Wong 2015). In this section, we begin by examining the effects of gasoline price shocks on U.S. inflation expectations within the same VAR model already discussed in Section 3.

Before reporting the results, it is useful to think through the mechanisms driving that response of household inflation expectations. We know from the work of Anderson et al. (2011, 2013) that household gasoline price expectations are well approximated by a random walk. This implies that households would not expect gasoline prices to increase following an unexpected surge in gasoline prices. Thus, if inflation expectations rise in response to a gasoline price shock, this response must reflect expectations of other consumer prices responding to the gasoline price shock.

The last two panels in Figure 1 quantify these effects. The positive response of the one-year household inflation expectation is clearly distinguishable from zero, but that of the 5-year inflation expectation is not. Moreover, the magnitude of the responses of inflation expectation is an order of magnitude smaller than the response of the inflation rate. Perhaps surprisingly, gasoline price shocks on average explain only 28% of the variation in 1-year Michigan Consumer Survey inflation expectations, and they explain only 6% of the variation in 5-year expectations (see Table 1). Of particular interest from a policy point of view is the extent to which gasoline price shocks have driven inflation expectations since late 2019. As shown in the lower panel of Figure 2, gasoline price shocks did contribute to the decline in 1-year inflation expectations in early 2020 as well as a noticeable increase in 2022, as one might have expected, but there was no material effect on the 5-year inflation expectation at any point, assuaging concerns over gasoline price shocks de-anchoring U.S. long-run inflation expectations.

Next, we examine the sensitivity of this result to employing an alternative measure of U.S. inflation expectations developed by the Cleveland Fed (see Haubrich, Pennacchi and Ritchken 2012). This measure is estimated using a model that combines Treasury yields, inflation rates, inflation swaps, and survey-based measures of inflation expectations. The resulting expectations measure is broader than the household survey measure and may be adapted to different horizons, but is also subject to model estimation and misspecification error. Here we focus on expectations at the 1, 3, 5, 10, 20 and 30 year horizons. These six variables replace the two household expectations measures in model (1). Otherwise, the VAR model specification remains unchanged.

Figure 4 shows evidence of a positive response of the Cleveland Fed inflation expectations at horizons as long as 30 years, but the magnitude of the response declines with the horizon and becomes indistinguishable from zero beyond the 10-year horizon. It may seem surprising that there would be an unambiguously positive response at the 5-year horizon, given that the Michigan survey data did not show such a result. The difference is that the Michigan survey asks about "the outlook for prices over the next 5 to 10 years," so the responses of Michigan 5-year expectations are best compared to the 5 year/5 year forward rate of the Cleveland Fed inflation expectations measure, which may be approximated as 2 times the 10-year expectations minus the 5-year expectation. There is no evidence that the response in that measure is distinguishable from zero, suggesting that the results for the longer horizon rates are driven by the positive short-run response of inflation expectations to a gasoline price shock.

Do these impulse responses overturn our earlier conclusions about the cumulative impact of gasoline price shocks after 2019? Figure 5 shows that except at the 1-year horizon, the contribution of gasoline price shocks since 2019 has been negligible. By far the largest effect occurs during the economic slump in early 2020. The remaining effects are very small. These results corroborate the conclusion that there is no evidence that positive gasoline price shocks destabilize long-run inflation expectations.[6]

5. Inflation Responses to Energy Price Shocks in Major Economies

Concerns about the inflationary impact of oil price shocks are not limited to the United States. They apply equally to other OECD economies. Over the years, a number of studies have examined this impact (e.g., Boschen and Weise 2003; Choi et al. 2018; Conflitti and Luciani 2019;. De Gregorio 2012; Kilian 2008b). One additional challenge in this line of research is that oil is traded in global markets with the price denominated in U.S. dollars. The domestic price of fuels, in contrast, depends on the price of oil in domestic currency. This necessitates converting the global price of oil at the bilateral dollar exchange rate, when regressing inflation on the change in the price of oil. This adjustment is often overlooked in empirical work.

A more direct solution to this problem is to work with the domestic retail price of motor

[6] Our model focuses on the implications of an average gasoline price shock. Recently, Aastveit et al. (2023) suggest that, in forming their inflation expectations, households differentiate between oil price changes driven by global oil supply and oil price changes driven by global demand. Aastveit et al. fit a global oil market model augmented by U.S. inflation and inflation expectations on data starting in 1983. This approach not only ignores the distinction between global oil prices and domestic retail fuel prices, but it presumes that households not only track the price of oil, but have the ability to differentiate between oil demand and oil supply shocks. This assumption seems heroic, all the more so, as the distinction between oil supply and oil demand shocks was only introduced in Barsky and Kilian (2002) and was first made operational in Kilian (2009). This means that households could not possibly have been aware of the distinction between oil demand and oil supply shocks during the 1980s, 1990s and 2000s.

fuel, when available, which also controls for time variation in other cost components of the production of motor fuel. While this approach is useful in many contexts, it is not appealing when analyzing the evolution of inflation and inflation expectations following the Russian invasion of Ukraine in early 2022, which caused substantial increases not only in the price of motor fuel, but also in the prices of natural gas and electricity. One way of accommodating this concern is to focus on the consumer price index for energy more broadly.

In this section, we focus on the United States, Canada, Japan, the Euro area and the U.K. For each country, we fit a VAR(6) model with intercept including consumer energy price inflation, headline CPI inflation and core inflation (measured as CPI inflation excluding food and energy). The estimation period is 1997.2-2023.6, given that Euro area CPI data only become available in 1997.1. The identification as before relies on the pre-determinedness of the price of energy with respect to inflation.

$$\begin{pmatrix} u_t^{\Delta p^{energy}} \\ u_t^{\pi^{CPI}} \\ u_t^{\pi^{CPI,core}} \end{pmatrix} = \begin{bmatrix} * & 0 & 0 \\ * & * & * \\ * & * & * \end{bmatrix} \begin{pmatrix} w_t^{\text{nominal energy price}} \\ w_t^2 \\ w_t^3 \end{pmatrix}. \qquad (2)$$

Unlike in model (1), we do not include monthly household inflation expectations data since such data are not available for countries other than the United States.

Figure 6 confirms that the response estimates for the U.S. are largely unaffected by this omission and by focusing on energy prices as opposed to the price of gasoline. This result is consistent with evidence in Kilian and Zhou (2023). As before all responses have been normalized to correspond to a 10% consumer energy price shock. The inflationary impact of energy price shocks in other major economies depends on the share of energy in consumer expenditures, which tends to be higher in Europe (9%) compared to the U.S. (8%), for example, but lower in the U.K. (6%), and on the strength of trade unions, the industrial structure of the economy, and other determinants of the passthrough to core consumer prices. Three results stand out in Figure 6. First, the headline inflation responses in the U.K. and the Euro area are smaller on impact, but somewhat more persistent than for the United States or Canada. Even for the U.K. and the Euro area, however, these inflationary effects are statistically indistinguishable from zero at all but the shortest horizons. Second, the headline inflation response in Japan is even smaller. Third, the response of the core inflation rate generally is muted and indistinguishable from zero.

These differences become even more apparent when reporting the CPI level responses in Figure 7, which provide clear evidence of core consumer prices rising in response to the energy price shock in the U.K. and in the Euro area, but not in the other countries. Only for the U.K. and the Euro area is the probability mass of the core CPI response clearly concentrated in the positive region. This increase is also reflected in a steeper increase in headline consumer prices that makes up for the lower impact response.

Given these cross-country differences in how energy price shocks are transmitted to inflation, one may ask which country on average experiences the largest inflation variability, as energy prices fluctuate. Table 2 shows that on average energy price shocks explain 78% of the variation of headline inflation in the U.S., compared with as little as 20% in Japan. The Euro area, Canada, and the U.K. are in between these extremes. In contrast, energy price shocks accounted for 10% of the variability in Euro area core inflation compared with 6% in the U.S and in the U.K. and, at the other extreme, 3% in Canada and 2% in Japan.

This raises the question of whether the inflation rate in the Euro area since mid-2019 has been more or less responsive to energy price shocks than U.S. inflation. Figure 8 shows that indeed energy price shocks played a much larger role in driving Euro area headline inflation in late 2021 and in 2022 than in the U.S. For example, in March 2022, energy price shocks accounted for two thirds of the observed headline inflation rate. However, the contribution of these shocks to core inflation remained modest even in 2022. Clearly, the bulk of Euro area core inflation is not explained by energy price shocks.

The analysis of model (2) implicitly averages the responses to price shocks in different energy markets. It does not allow us to control for differences in the composition of energy price shocks over time, and it abstracts from the inflationary impact of energy price shocks in industry, which may face very different energy prices than households. These assumptions may be relaxed if more detailed energy price data are available. There are two main challenges. One is how to separately identify each of these energy price shocks, which requires careful attention to the institutional structure of energy markets. The other is that there are potentially many different energy prices faced by industry and not all of them are observed.

Kilian and Zhou (2023) recently attempted such an analysis for the U.S. economy. That study considered the individual and joint impact of shocks to the prices of gasoline, diesel fuel, jet fuel, natural gas, and electricity on CPI inflation. The key finding is that focusing on gasoline price shocks alone will underestimate the inflationary pressures emanating from the energy sector, but not enough to overturn the conclusion that much of the observed increase in U.S. headline inflation in 2021 and 2022 reflected non-energy price shocks.

6. Responses of Inflation Expectations in Other Major Economies

A question of obvious policy interest is whether long-term inflation expectations in Europe shifted in response to the major energy price shocks starting in 2020 and in particular after the Russian invasion of Ukraine in early 2022. This question may be addressed by extending the VAR model used in Section 5 to include measures of long-run inflation expectations. Unfortunately, with the exception of the United States, there are no readily available monthly survey data on households' long-run inflation expectations in OECD countries that date back to 1997. Nor are there extended monthly time series of financial market expectations derived from inflation-linked securities with the notable exception of the U.K.[7] In this section, we therefore extend the VAR(6) model for the U.K. estimated in Section 5 to include the 5-year, 10-year and 5 year/5 year inflation expectation implied by U.K. inflation-linked bonds.

Figure 9 shows positive responses of all measures of U.K. long-term inflation expectations to an energy price shock. As expected, the responses are declining in magnitude with the horizon of the inflation expectations and generally are indistinguishable from zero. The responses of the 5-year and 10-year expectations are broadly similar to those for the corresponding Cleveland Fed expectations. The response of the 5 year/5 year expectation is similar to that for the 5-year U.S. household inflation expectations in Figure 1. Figure 10 illustrates that the cumulative contribution of consumer energy price shocks to long-run inflation expectations in the U.K. has been quite small, even in 2022 and 2023 and confirms the earlier conclusion based on U.S. data that changes in long-run inflation expectations since 2020 reflected not so much energy price shocks, but other shocks to the economy. Likewise, the variance decomposition in Table 3 suggests that only 3% of the variation in the U.K. long-run inflation expectations are explained by consumer energy price shocks (see Table 3).

7. Concluding remarks

The analysis in this chapter focused on linear VAR estimates of the inflationary impact of energy price shocks. Equivalently, these effects could also be estimated based on linear local projections (LP). A related approach in the literature has been to employ country-level panel LP estimates of

[7] Even in the U.S., reliable data for Treasury Inflation-Protected Securities (TIPS) are only available since 2003, although trading started in 1997.

the inflationary impact (e.g., Baba and Lee 2022) That approach is problematic, however, not only because the global oil price tends to differ systematically from the domestic currency price of crude oil, but also because changes in the global price of oil are likely to be a poor approximation for changes in the domestic retail price of motor fuel. In addition, the panel approach is questionable because it imposes that the inflationary impact is the same across all countries, which is unlikely to be a good approximation.

Another question that has received some interest in the literature is whether the transmission of oil price shocks to inflation may be nonlinear. An early example is Hooker (2002). One class of models has included censored oil price variables in linear VAR models of inflation such as net oil price increases (e.g., Bernanke, Gertler and Watson 1997). This class of models has been formally shown to be invalid in Kilian and Vigfusson (2011) who proposed an alternative VAR methodology that allows for such nonlinearities. In related work, Goncalves et al. (2021) show that standard LP estimators of such models, as used in some recent studies, are not valid.

A related form of nonlinearity involves asymmetric responses to positive and negative energy price shocks. This question again can be addressed using the modified VAR approach of Kilian and Vigfusson (2011), but not by including energy price increases and/or decreases in linear VAR models or LP regressions. Asymmetries in the transmission of oil price shocks to inflation may arise from two sources: One is the transmission from oil prices to the price of fuels such as gasoline and the other is the transmission from gasoline price shocks to inflation. Existing evidence suggests that asymmetries in the transmission of oil price shocks to gasoline price shocks are present only at high data frequencies and vanish at the monthly frequency. The question of whether there is asymmetry in the inflationary impact of gasoline price shocks, depending on the direction of the shock, has not been formally examined, but we know that the direct effect of gasoline price shocks, which dominates the overall responses, must be symmetric by construction of the CPI, so approximate symmetry does seem empirically plausible.

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Table 1: Variability explained by U.S. gasoline price shocks (percent), 1990.4-2023.6

Headline CPI inflation	CPI inflation ex food and energy	1 yr household inflation expectation	5yr household inflation expectation
69.3	8.8	27.7	5.8
[65.5, 72.8]	[5.7, 13.0]	[21.3, 34.5]	[2.4, 11.5]

NOTES: Posterior median and 68% error band in brackets.

Table 2: Variability explained by domestic consumer energy price shocks (percent), 1997.2-2023.6

	U.S.	Canada	Japan	Euro Area	U.K.
Headline	78.5	59.8	19.8	65.9	43.9
Inflation	[74.3, 82.0]	[56.3, 63.3]	[15.7, 24.0]	[61.1, 70.3]	[39.0, 48.7]
Core	5.9	2.6	1.8	10.1	6.1
Inflation	[3.0, 10.2]	[1.5, 4.2]	[1.0, 3.0]	[6.2, 15.6]	[3.7, 9.4]

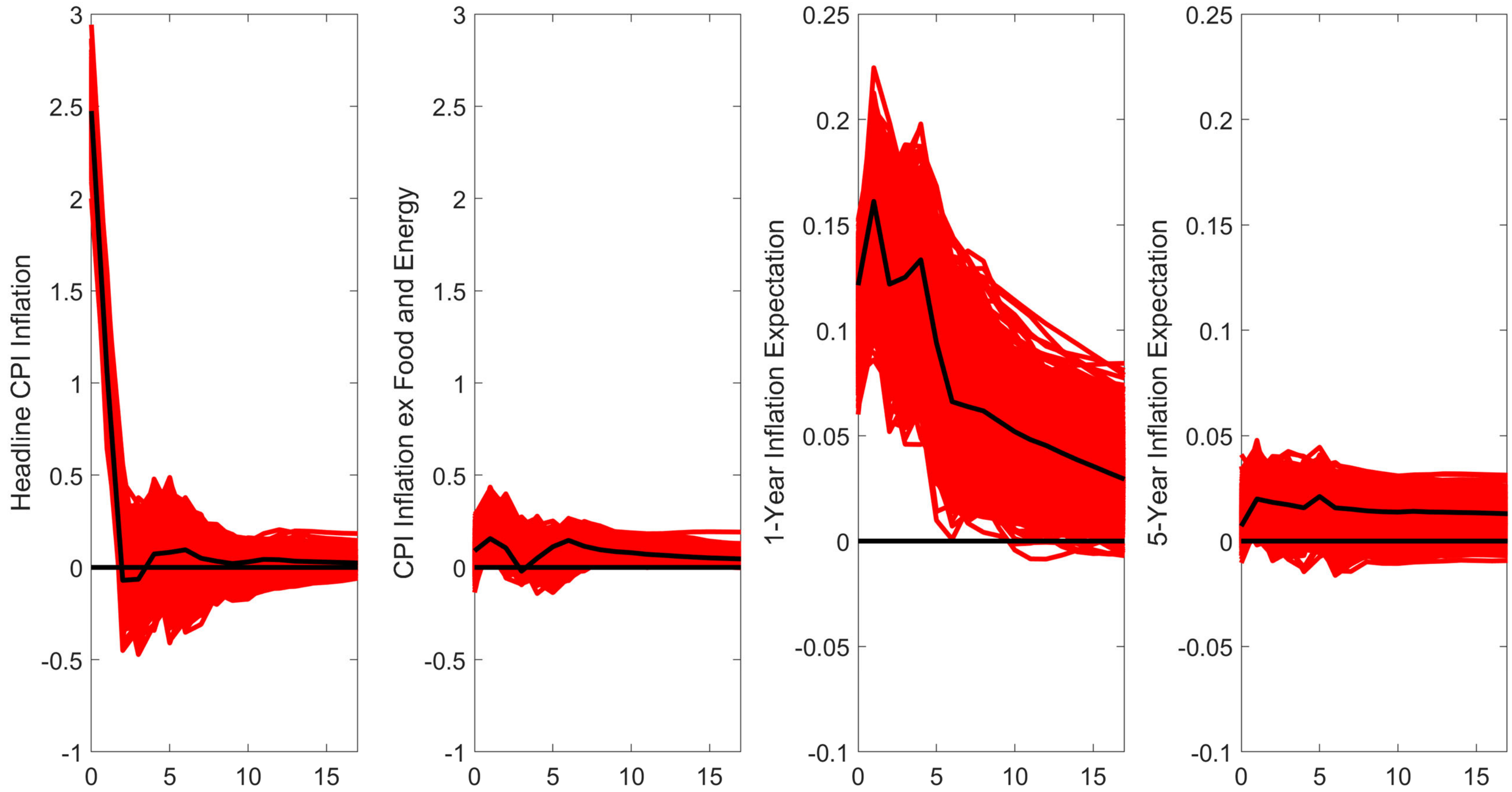
NOTES: Posterior median and 68% error band in brackets.

Table 3: Variability explained by domestic consumer energy price shocks (percent), 1997.2-2023.6

U.K. bond market long-run inflation expectations		
5-yr expectation	10-yr expectation	5 yr/5 yr expectation
2.7	3.2	3.1
[1.2, 5.9]	[1.2, 7.5]	[0.9, 8.1]

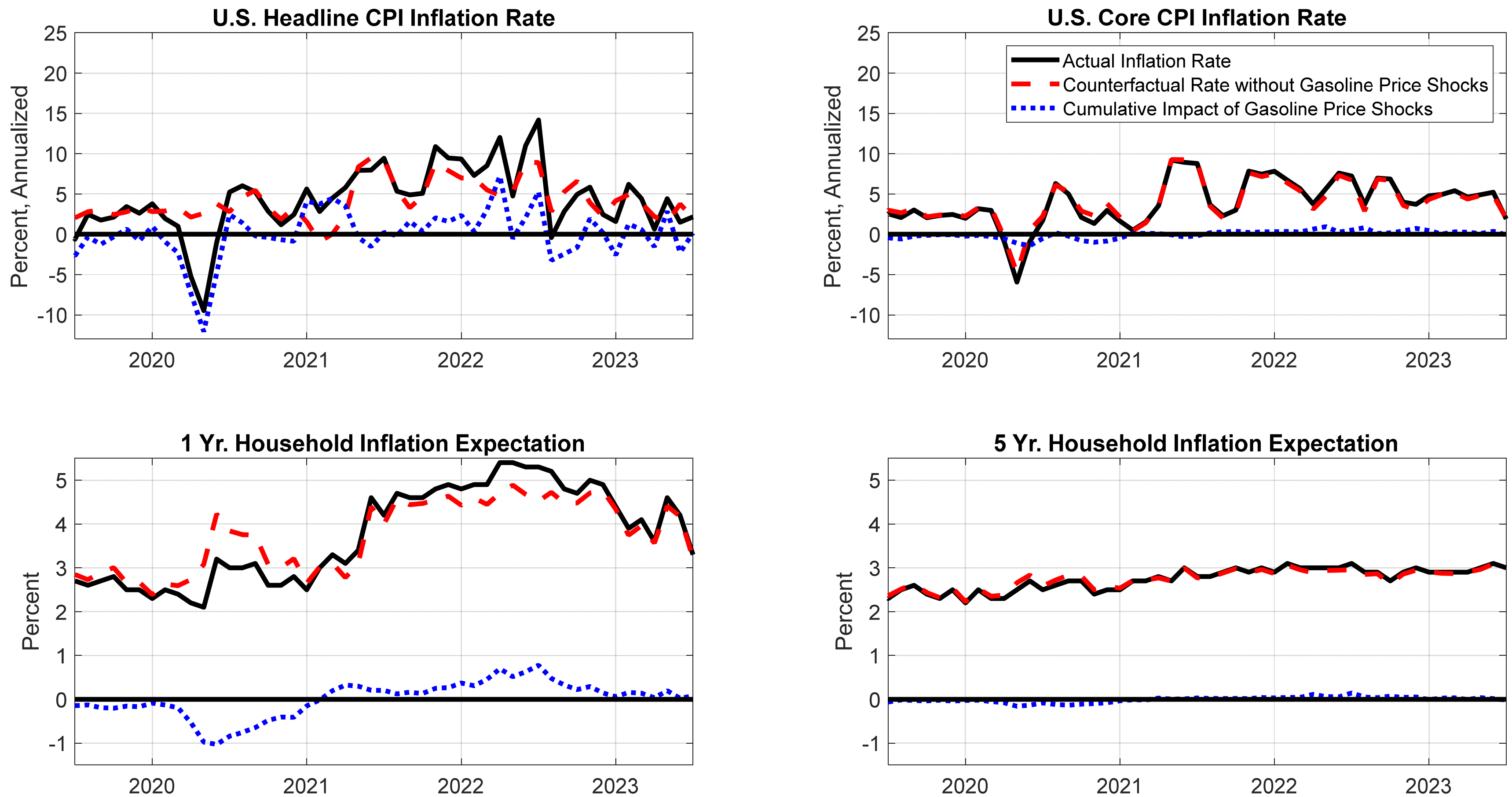
NOTES: Posterior median and 68% error band in brackets.

Figure 1: Responses to a 10% Gasoline Price Shock in the United States, 1990.4-2023.6



NOTES: Posterior median and 68% error band. The expectations data are from the Michigan Survey of Consumers.

Figure 2: Cumulative Contribution of U.S. Gasoline Price Shocks, 2019.6-2023.6



NOTES: See Figure 1.

Figure 3: Temporal Stability of the Responses to a 10% Gasoline Price Shock in the United States

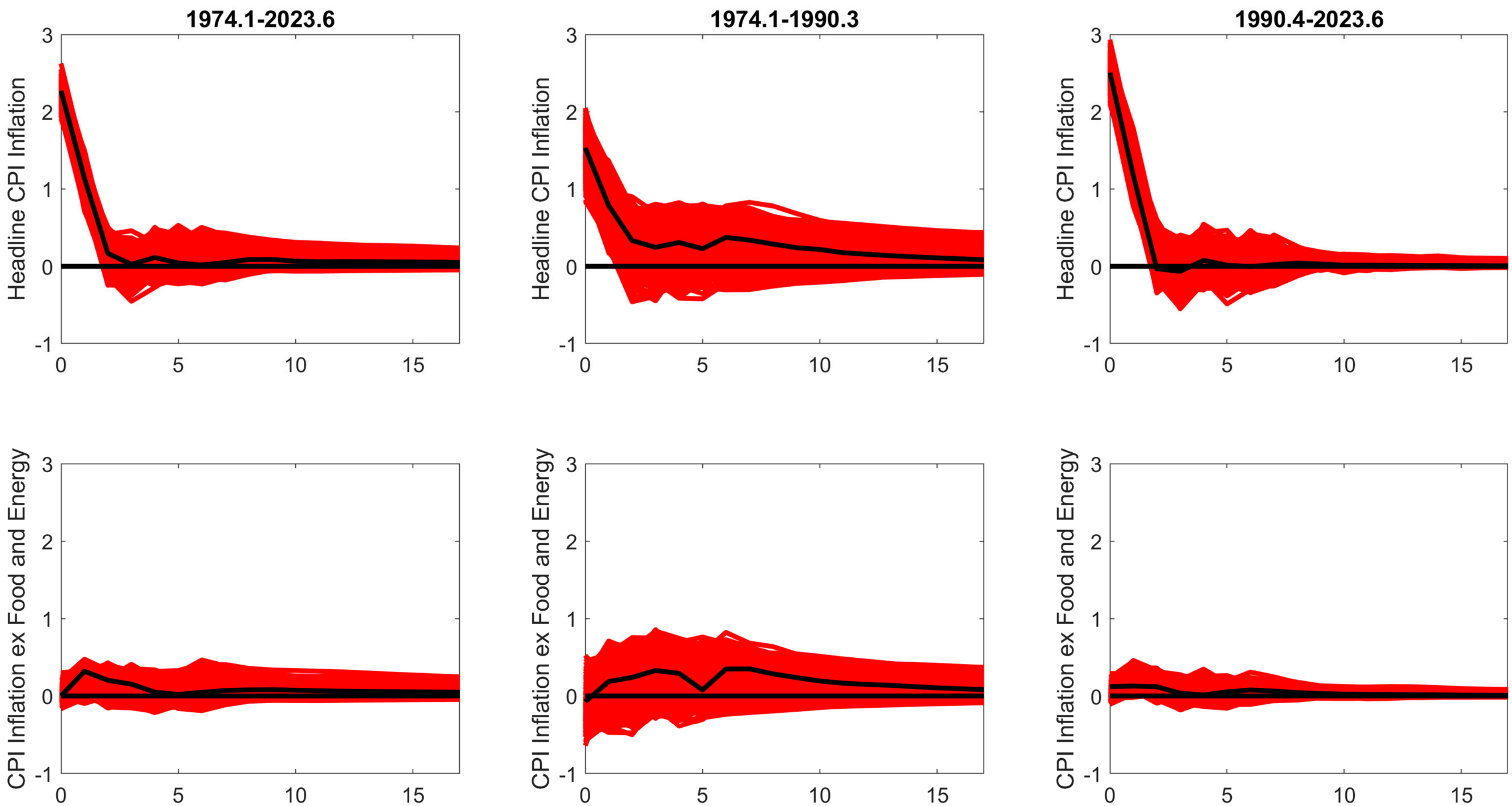
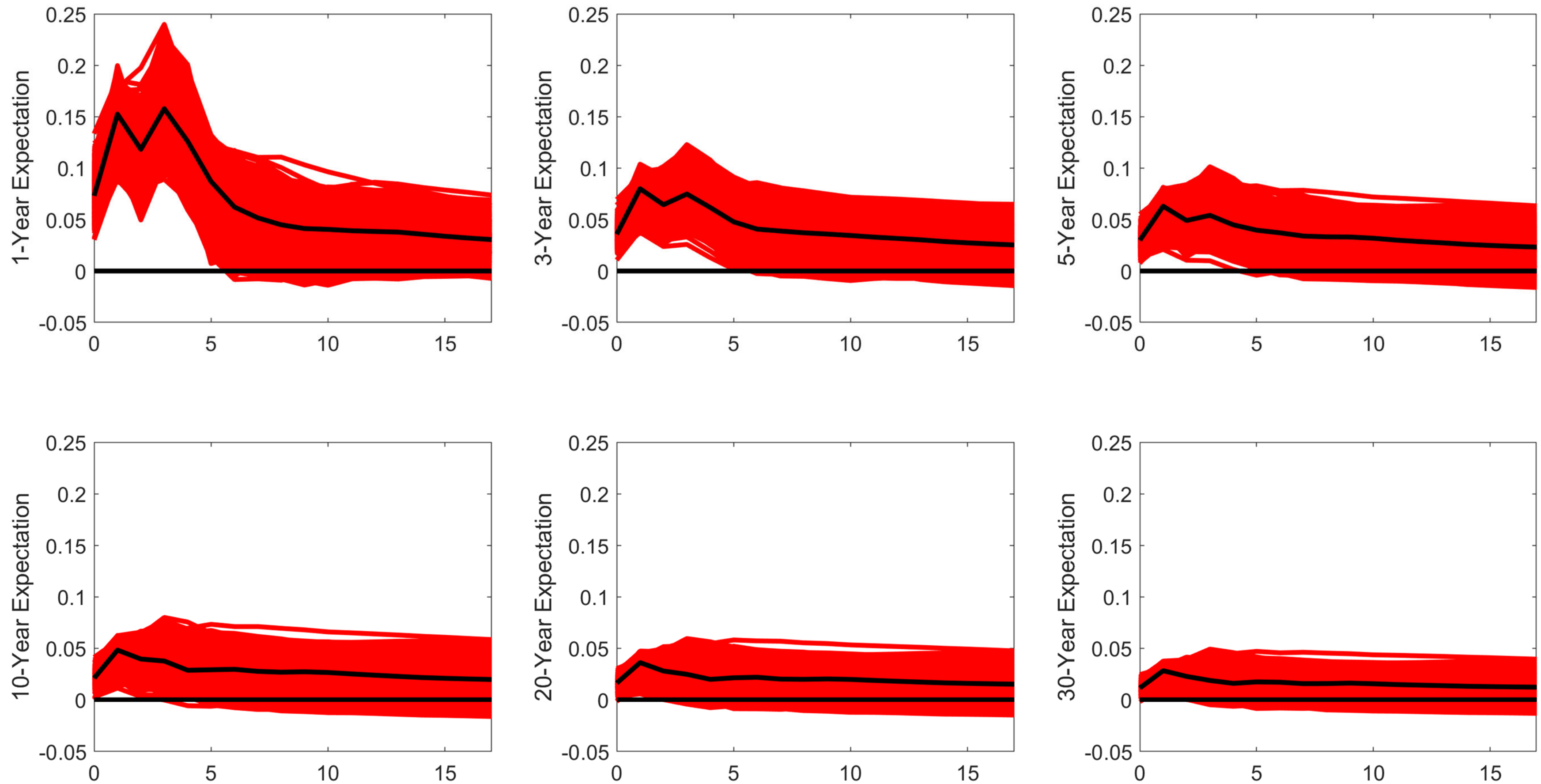


Figure 4: Responses of Cleveland Fed Inflation Expectations to a 10% Gasoline Price Shock, 1990.4-2023.6



NOTES: The Federal Reserve Bank of Cleveland estimates the expected rate of inflation over the next 30 years along with the inflation risk premium, the real risk premium, and the real interest rate. Their estimates are based on a model that combines Treasury yields, inflation rates, inflation swaps, and survey-based measures of inflation expectations.

Figure 5: Cumulative Contribution of Gasoline Price Shocks to Cleveland Fed Inflation Expectations

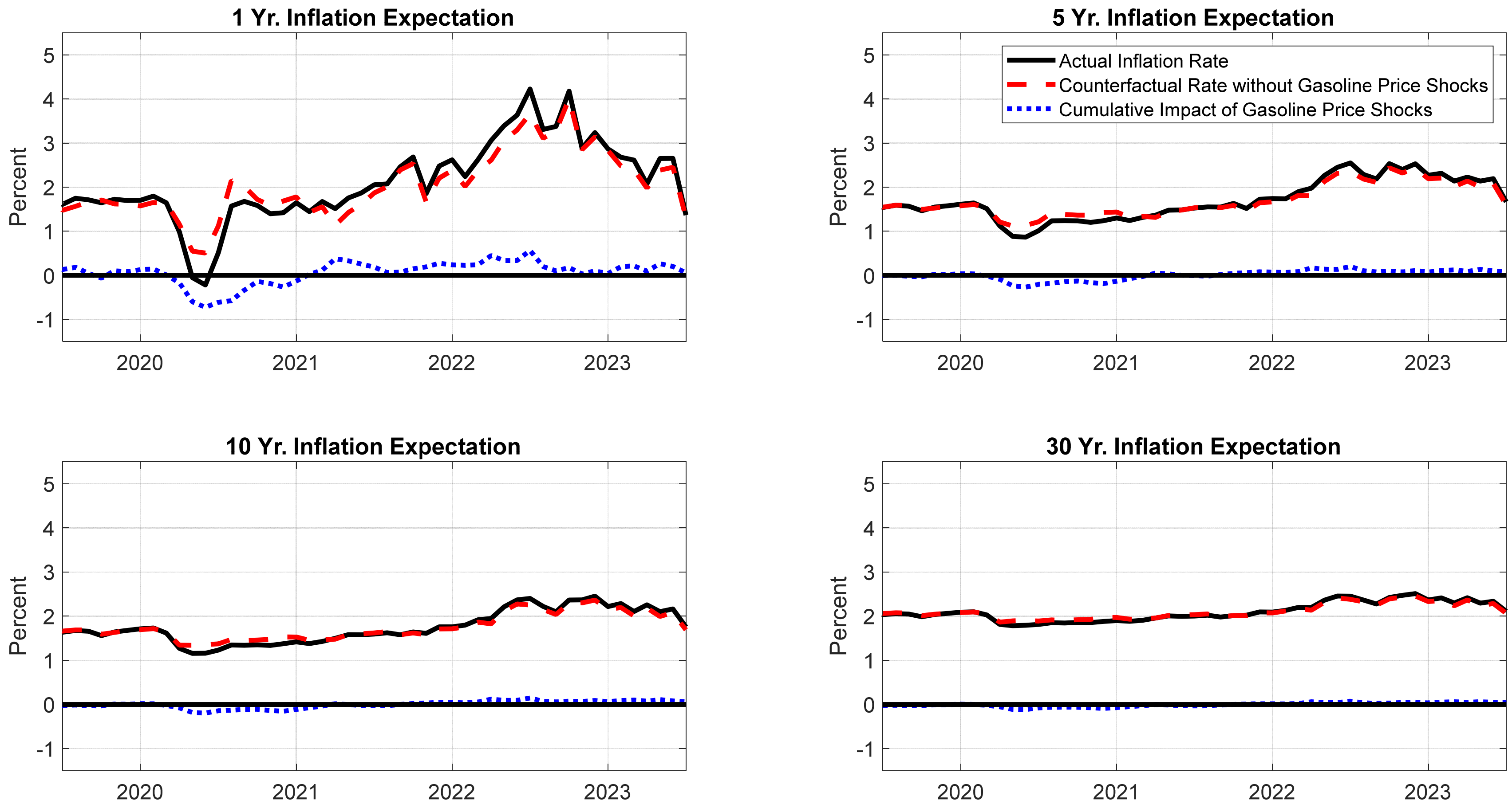
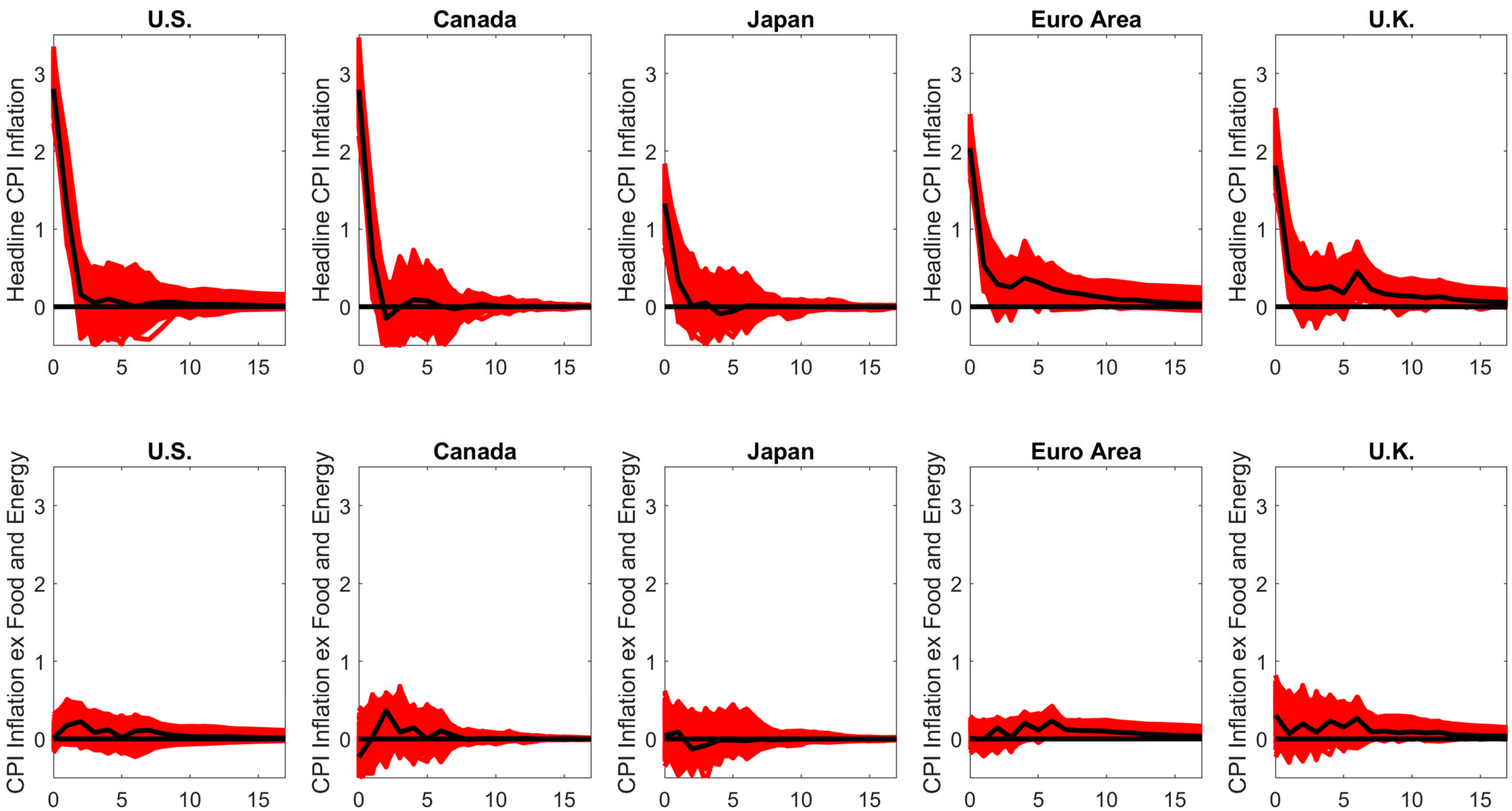
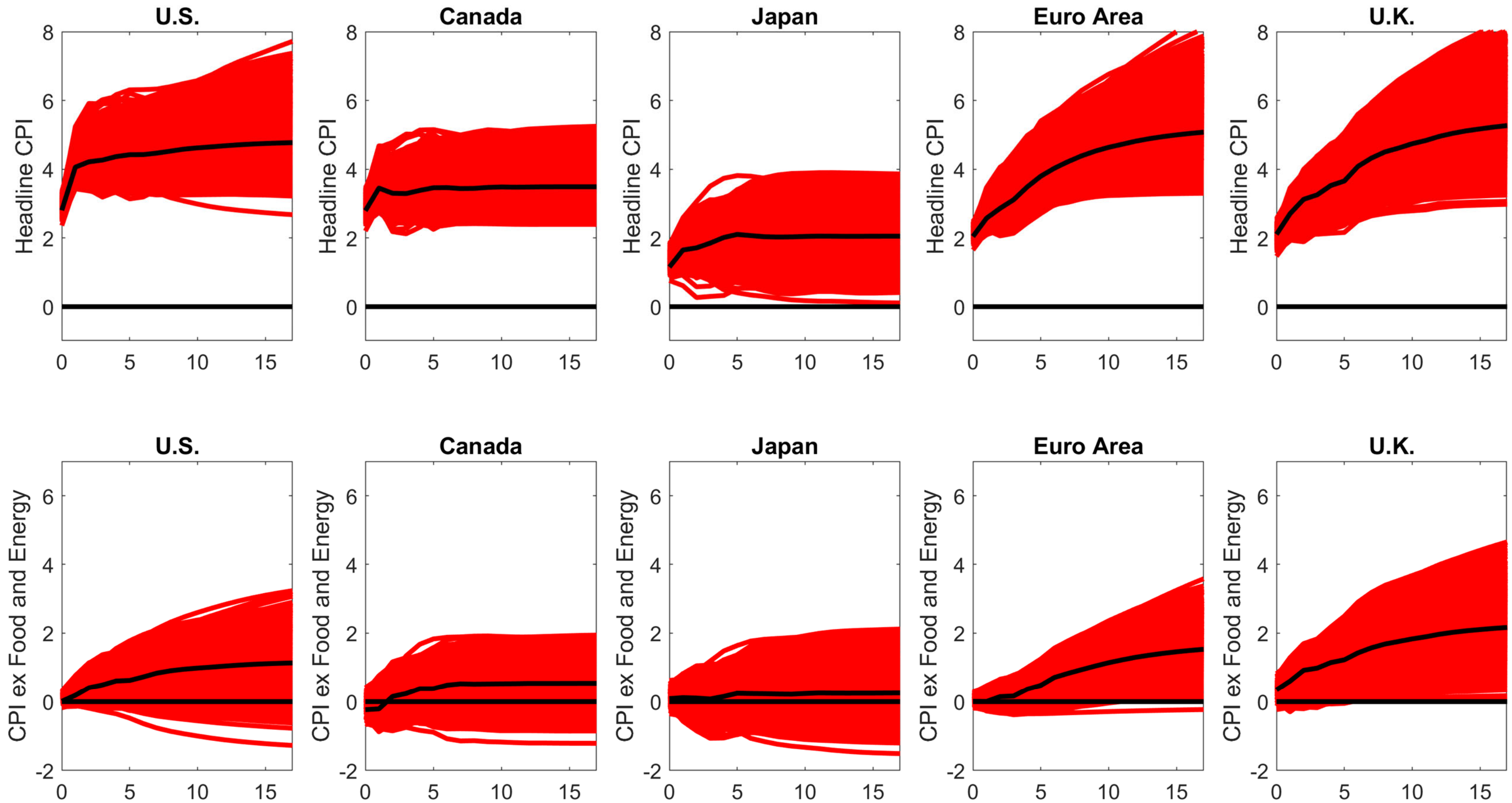


Figure 6: Inflationary Impact of a 10% Consumer Energy Price Shock, 1997.2-2023.6



NOTES: The core CPI for the U.K. also excludes tobacco and alcohol.

Figure 7: Cumulative Inflationary Impact of a 10% Consumer Energy Price Shock, 1997.2-2023.6



NOTES: The core CPI for the U.K. also excludes tobacco and alcohol.

Figure 8: Cumulative Contribution of Consumer Energy Price Shocks in the U.S. and Euro Area, 2019.1-2023.6

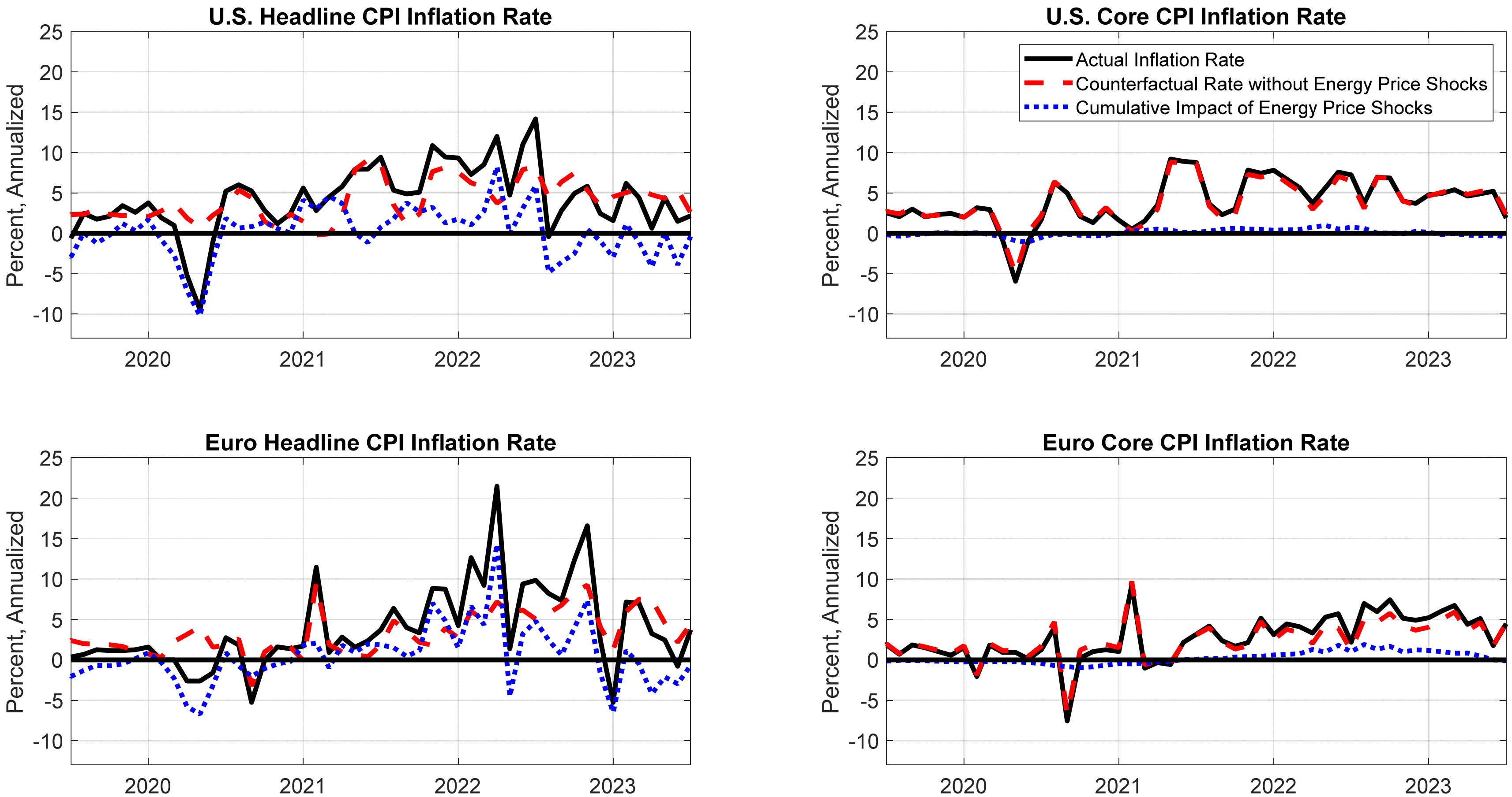


Figure 9: Responses of U.K. Bond Market Inflation Expectations to a 10% Consumer Energy Price Shock, 1997.2-2023.6

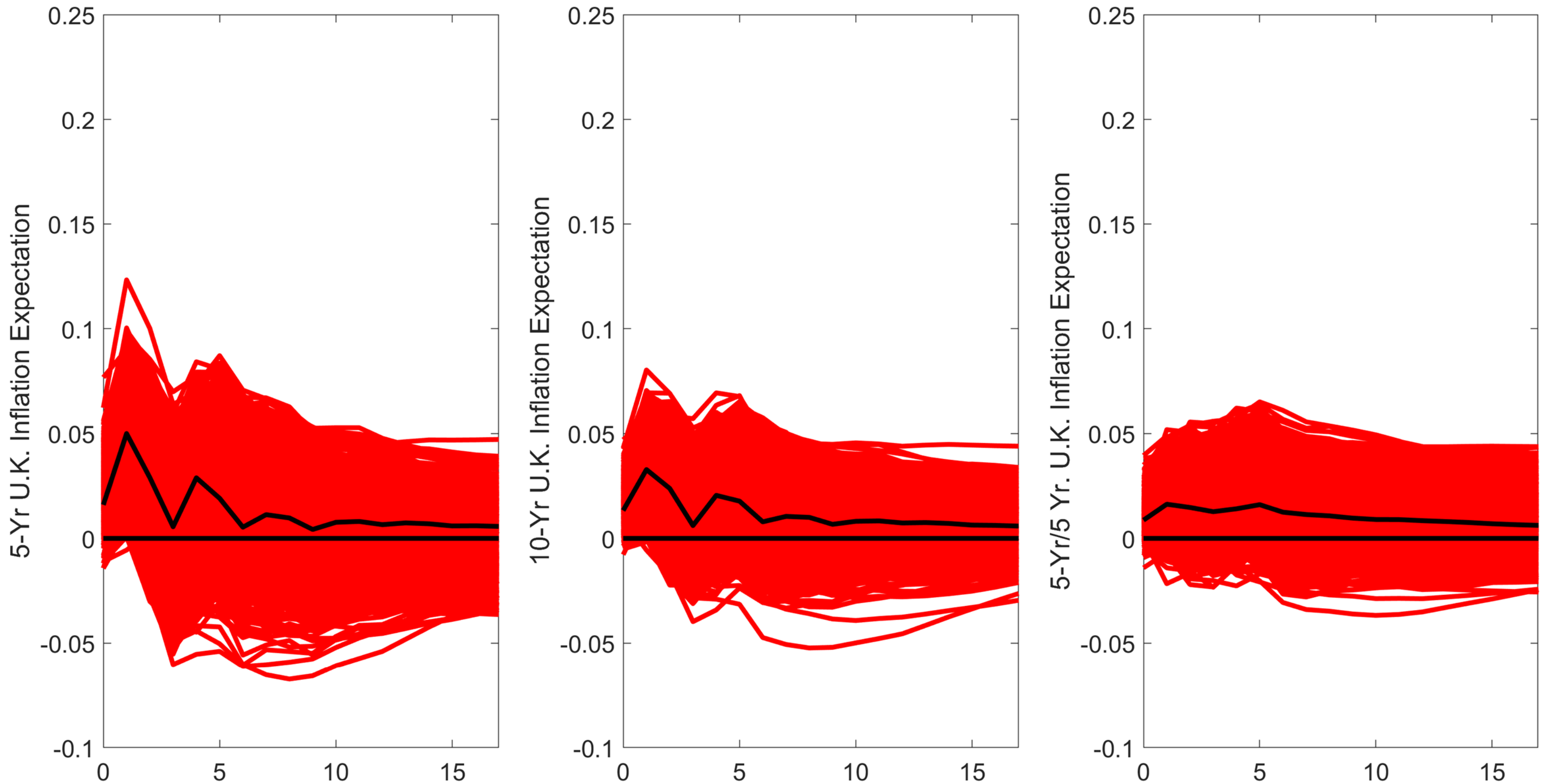


Figure 10: Cumulative Contribution of Consumer Energy Price Shocks to U.K. Bond Market Inflation Expectations, 2019.6-2023.6