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The Impact of Rising Oil Prices on U.S. Inflation and Inflation Expectations in 2020-23

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Predictions of oil prices reaching \$100 per barrel during the winter of 2021/22 have raised fears of persistently high inflation and rising inflation expectations for years to come. We show that these concerns have been overstated. A \$100 oil scenario of the type discussed by many observers, would only briefly raise monthly headline inflation, before fading rather quickly. However, the short-run effects on headline inflation would be sizable. For example, on a year-over-year basis, headline PCE inflation would increase by 1.8 percentage points at the end of 2021 under this scenario, and by 0.4 percentage points at the end of 2022. In contrast, the impact on measures of core inflation such as trimmed mean PCE inflation is only 0.4 and 0.3 percentage points in 2021 and 2022, respectively. These estimates already account for any increases in inflation expectations under the scenario. The peak response of the 1-year household inflation expectation would be 1.2 percentage points, while that of the 5-year expectation would be 0.2 percentage points.

JEL code: E31, E52, Q43

Key words: Scenario, inflation, expectation, oil price, gasoline price, household survey, core, pandemic, recovery.

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1. Introduction

The surge in inflation rates in 2021 reflected rising demand, as the economy adapted to the COVID-19 pandemic, tight labor markets, supply chain disruptions and the recovery of energy prices from their pandemic lows. With the price of West Texas Intermediate (WTI) oil rising above \$80/barrel in October 2021, concerns have grown that the oil price may climb as high as \$100/in the coming winter, as power plants in Europe and Asia switch to petroleum products in response to a shortage of coal and natural gas. Such a surge in oil demand combined with low oil inventories, inadequate oil production in OPEC+ countries and anemic growth in U.S. shale oil production could push the oil price to levels not seen since the early 2010s.

There are growing worries among policymakers and analysts that further, substantial oil price increases could push U.S. inflation higher for extended periods as well as drive up consumers' inflation expectations, as rising oil prices are reflected in retail gasoline prices. This could lead to inflation expectations becoming embedded in the wage and price setting process. For example, analysts at the Bank of America warned on October 1, 2021, that oil could surge above \$100 in the event of a cold winter and spark inflation (see Lee 2021). This sentiment is common on Wall Street. Similar views have been expressed by other investment banks including Goldman Sachs, JP Morgan and Barclay. Likewise, BlackRock, the world's top asset manager, recently stated that there is a high probability of oil hitting \$100 a barrel. Despite these warnings, there has been no quantitative analysis of this scenario.

These concerns prompt two key questions. First, to what extent have shocks to the gasoline price affected U.S. inflation and inflation expectations since the beginning of the pandemic? Second, how much further would a rise in the price of oil to \$100 in the winter of 2021/22 increase inflation and inflation expectations and how persistent would these effects be over the next two years? The latter question is closely related to the former, since what

matters to policymakers is the combined cumulative effect on inflation of gasoline price shocks that have already occurred and gasoline price shocks that are expected to occur, if the price of oil reaches \$100 per barrel in the coming winter.

We address these questions based on a structural vector autoregressive (VAR) model of the relationship between nominal retail gasoline prices, headline inflation, core inflation, and the Michigan Survey of Consumers median 1-year and 5-year inflation expectations. This model recognizes that it is gasoline prices rather than the price of crude oil that enter the consumer basket and that the gasoline price is what matters for the determination of household inflation expectations because of its salience (see, e.g., Coibion and Gorodnichenko 2015; Binder 2018). The identification of the model builds on insights in Kilian and Zhou (2021), who show that a structural VAR model is a more natural framework to estimate the effect of gasoline price shocks on inflation and inflation expectations than reduced-form correlations. In this paper, we take the analysis a step further by discussing how scenarios about the future evolution of the price of crude oil (such as the scenario entertained by the Bank of America) may be econometrically evaluated within our structural VAR model, along with the impact of past gasoline price shocks on inflation and inflation expectations.

We first show that gasoline price shocks account for much of the sharp temporary decline in headline inflation early in the COVID-19 pandemic. Gasoline price shocks started creating systematic inflationary pressures in early 2021, but, by September 2021, the cumulative impact of these gasoline price shocks had greatly diminished, indicating that much of the continued surge in core inflation and headline inflation at that point was driven by upward pressure on the prices of other goods. This suggests that the broad-based price increases from, for example, durable goods (vehicles, furniture, consumer electronics), shelter (rent and owners' equivalent rent) and other services (such as medical care) will be

the main drivers of inflation in the years to come. These pressures are likely to persist, even if oil and gasoline prices were to stabilize at current levels.

We then examine how renewed gasoline price increases after September 2021 in response to the oil price reaching \$100 per barrel in the winter of 2021/22, as conjectured by many market observers, would affect inflation and inflation expectations. We show that concerns about persistently high headline inflation in 2022 and 2023 in response to this scenario have been overstated. A \$100 oil scenario would only briefly raise monthly headline inflation, before fading rather quickly. However, the short-run effects on headline inflation would be sizable.

The precise magnitude of the impact on inflation differs depending on whether we focus on CPI or PCE headline inflation. On a year-over-year basis, under the \$100 oil scenario, headline CPI inflation would increase by an additional 3 percentage points by the end of 2021, and headline PCE inflation by an additional 1.8 percentage points. By the end of 2022, the impact would drop to 0.4 percentage points for either inflation measure. By 2023, the effect would be effectively zero. By comparison, core CPI inflation and trimmed mean PCE inflation measures suggest a much more modest impact. On a year-over-year basis, they would rise by 0.5 and 0.3 percentage points at the end of 2021, respectively, and by 0.4 percentage points for either measure at the end of 2022.

All these estimates already incorporate the effect higher gasoline prices may have on inflation expectations. We find that under the scenario the cumulative effect of gasoline price shocks on 1-year inflation expectations rises to 1.2 percentage points in late 2021, before gradually declining. The effect on 5-year inflation expectations is much smaller with a peak increase of only 0.2 percentage points, suggesting that 5-year household inflation are hardly affected by gasoline price shocks.

Our work relates to a large literature on how household survey inflation expectations

respond to oil and gasoline price shocks (see, e.g., Coibion and Gorodnichenko 2015; Wong 2015; Binder 2018; Conflitti and Cristadoro 2018; Binder and Makridis 2021; Kilian and Zhou 2021). In addition, our analysis is related to earlier empirical work on how oil and gasoline price shocks are transmitted to inflation (see, e.g., Kilian 2009; Clark and Terry 2010; Kilian and Lewis 2011; Wong 2015; Conflitti and Luciani 2019; Kilian and Zhou 2021). Our analysis differs from this earlier literature not only in that we are the first to examine the major fluctuations in inflation and inflation expectations during the COVID-19 pandemic. We also go beyond quantifying inflationary effects in the historical data and show how to evaluate hypothetical scenarios for the future evolution of oil and gasoline prices and their impact on inflation and inflation expectations. Moreover, we consider both short-term and long-term household inflation expectations and we report results for a range of alternative inflation measures of interest to policymakers rather than just monthly headline inflation.

The remainder of the paper is organized as follows. In section 2, we introduce a structural VAR model that allows us to answer the questions of interest under minimal assumptions and we discuss the econometric tools required for the analysis of scenarios. Section 3 reports results for the CPI inflation measures most commonly discussed in the press and for household inflation expectations. Section 4 reports the corresponding results for the PCE inflation measures favored by central bankers. Section 5 examines the implications of our estimates for year-over-year inflation rates. The concluding remarks are in Section 6.

2. The Structural VAR Model

Let $y_t = [\Delta p_{gas}_t, \pi_t, core \pi_t, \pi_t^{1-yr \text{ exp}}, \pi_t^{5-yr \text{ exp}}]'$, where Δp_{gas}_t denotes the growth rate of the nominal U.S. retail price for unleaded gasoline, π_t is the headline inflation rate, $core \pi_t$ is a measure of core inflation, and $\pi_t^{1-yr \text{ exp}}$ and $\pi_t^{5-yr \text{ exp}}$ are the Michigan Survey of Consumers'

measure of the median household expectation of inflation over the next year and the next five years, respectively. We postulate that these data are jointly explained by a structural VAR model. We consider two variants of the model. One is based on headline CPI inflation and inflation in the CPI excluding food and energy, as a measure of core inflation. The other is based on headline PCE inflation and the trimmed mean of PCE inflation as the measure of core inflation. We also selectively report additional results for core PCE inflation. All variables are measured in percent (see Figure 1).¹

2.1. Model structure

The structural VAR model can be written as $B_0 y_t = B_1 y_{t-1} + \dots + B_p y_{t-p} + w_t$, where y_t is the 5×1 vector of date t observations for $t = p+1, \dots, T$, w_t denotes the vector of mutually uncorrelated i.i.d. structural shocks and B_i , $i = 0, \dots, p$, represent 5×5 dimensional coefficient matrices. The intercept has been dropped for expository purposes. The reduced-form VAR model representation is $y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + u_t$, where $A_i = B_0^{-1} B_i$, $i = 1, \dots, p$, and $u_t = B_0^{-1} w_t$. We set the lag order, p , to a conservative upper bound of 12 lags (see Kilian and Lütkepohl 2017). The model explains variation in the data in terms of the structural shocks w_t . The model is partially identified in that only the first structural shock is identified. The estimates of the responses to this shock are invariant to the identification of the remaining structural shocks (see Christiano, Eichenbaum and Evans 1999).

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). Under our identifying assumption

¹ The CPI and PCE data are available in FRED. The gasoline price data were obtained from the U.S. Energy Administration's *Monthly Energy Review*. The inflation expectations data were downloaded directly from the website of the Survey Research Center at the University of Michigan.

$$\begin{pmatrix} u_t^{\Delta p_{gas}} \\ u_t^{\pi^{CPI}} \\ u_t^{core \pi^{CPI}} \\ u_t^{\pi^{1-yr \ exp}} \\ u_t^{\pi^{5-yr \ exp}} \end{pmatrix} = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & * & * & * \\ * & * & * & * & * \\ * & * & * & * & * \\ * & * & * & * & * \end{bmatrix} \begin{pmatrix} w_t^{\text{nominal gasoline price}} \\ w_t^2 \\ w_t^3 \\ w_t^4 \\ w_t^5 \end{pmatrix} \quad (1)$$

and

$$\begin{pmatrix} u_t^{\Delta p_{gas}} \\ u_t^{\pi^{PCE}} \\ u_t^{\text{trimmed mean } \pi^{PCE}} \\ u_t^{\pi^{1-yr \ exp}} \\ u_t^{\pi^{5-yr \ exp}} \end{pmatrix} = \begin{bmatrix} * & 0 & 0 & 0 & 0 \\ * & * & * & * & * \\ * & * & * & * & * \\ * & * & * & * & * \\ * & * & * & * & * \end{bmatrix} \begin{pmatrix} w_t^{\text{nominal gasoline price}} \\ w_t^2 \\ w_t^3 \\ w_t^4 \\ w_t^5 \end{pmatrix}. \quad (2)$$

The use of a partially identified model not only dispenses with the need for potentially controversial additional identifying assumptions, but also facilitates the construction of scenarios for the identified shock. Models (1) and (2) are an extension of a lower-dimensional model examined and validated in Kilian and Zhou (2021) who show that in their setting very similar results are obtained under a range of alternative, more restrictive identifying assumptions.

Since the 5-year inflation expectations data are available only starting in 1990.4, the model is estimated on monthly data starting in 1990.4 and ending in 2021.9. We follow the Bayesian approach described in Arias, Rubio-Ramirez and Waggoner (2018) and postulate a diffuse Gaussian-inverse Wishart prior for the reduced-form parameters, as in Karlsson (2013). The prior of the VAR slope parameter vector is $\beta \sim N(\beta_0, \Sigma \otimes \Omega_0)$, where the prior mean β_0 is set to zero, Ω_0 is a diagonal matrix with j^{th} diagonal element $(1/\sigma_j^2)(0.2/l)^2$, σ_j^2 is approximated as the residual variance of an AR(1) regression for variable j , l indicates the lag, and $\Sigma \sim IW(S_0, \alpha_0)$ with $\alpha_0 = 7$ and

$$S_0 = (\alpha_0 - 5 - 1) \begin{pmatrix} \sigma_1^2 & 0 & 0 & 0 \\ 0 & \sigma_2^2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \sigma_5^2 \end{pmatrix}.$$

2.2. Econometric evaluation of the structural model

Having simulated the posterior distribution of the structural impulse responses, we evaluate the joint distribution of all identified impulse responses under additively separable absolute loss, as discussed in Inoue and Kilian (2021). We construct the Bayes estimator of the impulse response vector by minimizing in expectation the loss function, and we approximate the corresponding lowest posterior risk joint credible set.

Likewise, we evaluate the path of the historical decompositions jointly under the same loss function. We start by computing, for each posterior draw, the expected path of the variables of interest in the absence of future shocks based on the structural moving average decomposition in the estimated model. Let

$$y_t \approx \sum_{i=0}^{t-1} \Theta_i w_{t-i},$$

where y_t denotes the vector of the data at date $t = 1, \dots, T$, T denotes September 2021 in our application, Θ_i is the 5×5 matrix of impulse response coefficients at horizon i whose elements are denoted by $\theta_{kl,i}$, and w_t denotes the vector of structural shocks. Then the fitted value

$$\hat{y}_{kt}^{(1)} = \sum_{i=0}^{t-1} \hat{\theta}_{k1,i} \hat{w}_{1,t-i},$$

measures the cumulative causal effect of gasoline price shocks on variable $k = 1, \dots, 5$.

This structural moving average representation also provides the starting point for evaluating scenarios about the future price of crude oil. This requires mapping the hypothesized change in the price of crude oil into the corresponding change in the retail price

of gasoline from October 2021 until December 2023. We refer to the resulting path for the growth rate of the price of gasoline as the target growth rate. We estimate the expected path of each model variable in the absence of future shocks by iterating this expression forward for 27 months beyond the end of the sample, given $w_{T+1} = \dots = w_{T+27} = 0$. We then compare the expected path for the growth rate of the price of gasoline in the structural VAR model with the targeted growth rate of gasoline prices (adjusted for the mean change in this growth rate) under the scenario, denoted x_{T+1}, \dots, x_{T+27} .

This allows us to recursively infer, for each posterior draw, the magnitude of the gasoline price shock required for the predicted growth rate, $\hat{x}_{T+1}, \dots, \hat{x}_{T+27}$, to match its targeted value. Let w_{1j}^c denote the counterfactual exogenous gasoline price shock at date j , where $w_{1j}^c = w_{1j}$ for $j \leq T$. Then

$$w_{1j}^c = \frac{(x_j - \hat{x}_{1j})}{\theta_{11,j}}, \quad j = T + 1, \dots, T + 27,$$

where $\hat{x}_{1t} = \sum_{j=1}^4 \hat{x}_{1t}^{(j)}$ and $\hat{x}_{1t}^{(j)} = \sum_{i=0}^{t-1} \hat{\theta}_{1j,i} w_{j,t-i}^c$ are updated recursively, while $\hat{x}_{1t}^{(j)} = \hat{y}_{1t}^{(j)}$ for $j \neq 1$. The resulting counterfactual shock sequence is then imposed in generating future realizations of all variables of interest from the structural moving average representation for $T + 1, \dots, T + 27$. This allows us to extrapolate the cumulative impact of gasoline price shocks on the model variables from the past into the future.² We evaluate the posterior draws of the paths of each variable of interest under additively separable loss, as discussed in Inoue and Kilian (2021), and construct the Bayes estimate as well as approximations to the corresponding lowest posterior risk joint credible sets.

² A similar approach has been used in Kilian and Zhou (2020) for assessing the impact of a hypothetical reduction in the U.S. Strategic Petroleum Reserve on fiscal revenues.

3. Empirical Analysis of CPI Inflation

Model (1) focuses on CPI inflation which is the measure of inflation most closely observed by the public and most widely discussed in the press. In contrast, monetary policy decisions are based on PCE inflation measures, as included in model (2). There are important differences in how these inflation measures are constructed and what expenditure weights they use. For example, the CPI does not cover all health-related expenses of consumers, but attaches a larger weight to housing expenses. Moreover, the PCE price index is constructed taking into account additional data from business surveys and administrative data. An interesting question therefore is whether this distinction makes a difference for the impact of gasoline price shocks. When discussing the estimates of model (2) in section 4, we will show that there are indeed important differences across CPI and PCE inflation data.

3.1. How do CPI inflation and inflation expectations respond to nominal gasoline price shocks?

A positive nominal gasoline price shock causes a persistent appreciation of the price of gasoline. Figure 2 shows the responses of the other variables in model (1) to an unexpected increase in the nominal retail price of gasoline. It shows a sharp and precisely estimated increase in headline inflation on impact that dies out after two months.

While the general public tends to focus on headline CPI inflation, economists tend to exclude volatile components of the CPI such as food or energy in an effort to measure broader inflationary pressures. One such inflation measure is based on the CPI excluding food and energy (often referred to as core CPI inflation). There are two reasons to expect gasoline price shocks to be associated with broader inflationary pressures. One is that gasoline price shocks have been shown to be a bellwether for broader demand shifts in the domestic economy. Since demand shifts may be persistent, one would expect gasoline price increases to be followed by other consumer price increases. The other reason is that higher

gasoline price shocks also may directly and indirectly affect the cost of producing other goods. To the extent that these cost increases are being passed on to the consumer, it would not be surprising to see a delayed positive response in non-energy consumer prices. Figure 2 addresses this question. It shows a much smaller and less precisely estimated initial response of core CPI inflation than for headline CPI inflation. At longer horizons, the responses are positive, but small and diminishing with the horizon. There is no evidence of large spillovers into core CPI inflation or of large secondary inflation increases, as implied by models of wage-price spirals (see Blanchard 1986).³

Finally, Figure 2 shows a response of 1-year inflation expectations that is much smaller than that of headline CPI inflation, but more persistent and remains precisely estimated for the first seven months. The response of 5-year inflation expectations is also persistent, but even smaller and precisely estimated only at short horizons.⁴ Thus, there is clear evidence that gasoline price shocks matter for all model variables, albeit to different degrees.

The estimated model (1) also indicates that over our estimation period gasoline price shocks accounted for 63% of the variability in the headline CPI inflation rate, but only 7% of the variability in the core CPI inflation rate. At the same time, gasoline price shocks explain 38% of the variability in 1-year inflation expectations, but only 14% of the variability in 5-year inflation expectations (see Table 1). Of course, there may be substantial differences in the explanatory power of gasoline price shocks over time. Next, we therefore quantify the

³ The wage-price spiral, as discussed in Blanchard (1986), for example, refers to a 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.

⁴ It should be kept in mind that our analysis speaks to the component of inflation and inflation expectations driven by gasoline price shocks. Obviously, rising gasoline prices are only one source of inflationary pressures. The estimates in this paper by construction do not incorporate broader cost pressures from tight labor markets and sustained disruptions of supply chains, which have also been putting upward pressure on U.S. consumer prices and price expectations during the pandemic.

extent to which gasoline price shocks caused inflation and inflation expectations to move from June 2019 until September 2021 specifically, when the Covid-19 pandemic triggered major gasoline price fluctuations.

3.2. How much of the evolution of CPI inflation and inflation expectations up to September 2021 must be attributed to nominal gasoline price shocks?

Figure 3 plots the cumulative contribution of gasoline price shocks to headline CPI inflation rates based on the estimated model. A positive value indicates by how many percentage points all gasoline price shocks to date have raised inflation in that month (expressed as annualized rates); a negative value indicates by how much they have lowered inflation in that month.

The unexpected drop in gasoline prices in early 2020, as the pandemic paralyzed the U.S. economy, lowered headline inflation by 9 percentage points on an annualized basis. This drop explains nearly all of the temporary decline in inflation during that period. Starting in May, the economy and hence gasoline prices began to recover. Inflation briefly spiked in June 2020 as a result. It was only in December 2020, however, that gasoline price shocks started to persistently raise headline inflation. In early 2021, the recovery in gasoline prices added as much as 4.9 percentage points to headline inflation. This effect starting waning later in the summer of 2021. As of September 2021, the impact of gasoline price shocks had become negligible. This point is of some interest because it suggests that the continued surge in headline CPI inflation at that point was not driven by energy price shocks, but by price pressures resulting from supply bottlenecks and tight labor markets that may be less transitory.

Not surprisingly, the cumulative effect on monthly core CPI inflation was much more muted (see Figure 4). There is evidence of a decline in core CPI inflation from 2020 through early 2021 by as much as 0.9 percentage point on an annualized basis. This decline is

reversed only in mid-2020. Starting in 2021, the impact of gasoline price shocks rises to 0.6 percentage points, only to largely vanish by September 2021.

The fall and rise in gasoline prices during the pandemic are also reflected in household inflation expectations. Figure 5 shows the response of households' 1-year inflation expectations to all gasoline price shocks to date. There is clear evidence that unexpected gasoline price fluctuations temporarily lowered inflation expectations by as much as 0.8 percentage points at the height of the lockdown. As the price of gasoline recovered, it pushed inflation expectations up by as much as 0.6 percentage points by August 2021. In contrast, the response of 5-year inflation expectations in Figure 6 is muted at best. Following a modest decline by 0.1 percentage points in early 2020, it barely recovered to zero by September 2021. This evidence shows that gasoline price shocks have played an important role in driving both headline CPI inflation rates and one-year inflation expectations during the pandemic.

3.3. How much additional CPI inflation would a further rise in the price of oil to \$100 per barrel imply and how persistent would this effect be?

The surge in inflation rates and inflation expectations by September 2021 raises the question of how much further a rise in the price of oil to \$100/barrel would increase inflation and inflation expectations and how long these effects would last. We address this question by modeling this situation within our structural model. We start by describing a scenario for the WTI price of oil that reflects the concerns articulated by the Bank of America analysts and other observers.

3.3.1. A \$100 Oil Scenario

In our thought experiment, the price of WTI crude oil gradually rises from \$72 in September 2021 to \$100 in December 2021 and remains at that level through February 2022, before gradually dropping off to a long-run level of \$80 (see Figure 7). The assumption of rising oil

prices from October to December reflects the view that the market will tighten considerably, as consumers of fuels including power plants scramble to find supplies, while inventories are already low. During December through February, when temperatures are at their lowest, the price is expected to peak at \$100/barrel. The assumption of a decline in the oil price starting in March 2022 reflects lower oil consumption, as the weather warms. The assumption that the price remains constant in the long run is equivalent to assuming that the price of oil is not expected to change from May 2022 to December 2023. Similar results would be obtained with a long-run price of \$70/barrel. This scenario ignores the demand destruction expected at higher oil prices as well possible supply responses from OPEC+ or other producers. It implicitly assumes that the winter in the northern hemisphere will be unusually harsh and that the global supply of oil will remain constrained. This makes it of particular interest for assessing the upside inflation risks associated with the oil market.

3.3.2. Implications of the scenario for CPI inflation and inflation expectations

Under our thought experiment, the growth rate in the nominal U.S. retail price of gasoline is half of the growth rate of the price of oil in Figure 7, given that the share of crude oil in the cost of producing gasoline is roughly 50%. We use the estimates of our structural model to simulate the evolution of headline inflation and inflation expectations under the maintained assumption that the change in gasoline prices follows this hypothesized path, while setting all other shocks in the model to zero in expectation, as discussed in section 2. Since oil and gasoline markets have experienced even larger price fluctuations historically than modeled under our scenario and since the estimates of structural models such as ours have been shown to be stable over time in related research, there is no reason to discount the implications of the estimated structural model for the 2021-23 period.⁵

⁵ The analysis of scenarios based on structural VAR models is valid only to the extent that the hypothesized shock sequence does not cause economic agents to change their behavior, rendering the structural model

Figure 3 shows that this scenario is associated with a rise in headline inflation not unlike that caused by gasoline price shocks in early 2021, but starting at a higher base level. At the peak, gasoline price shocks add 5.7 percentage points to annualized monthly inflation. This effect quickly fades in 2022, however, and becomes negligible by 2023. In other words, the inflationary effects of positive gasoline price shocks vanish almost as soon as gasoline prices stop rising. The inflationary effects on core CPI inflation peak in late 2021 at only 1.3 percentage points and then largely vanish in 2022 and 2023 (see Figure 4).

Figure 5 showed that one-year inflation expectations had already peaked at 0.6 percentage points in August 2021 in response to earlier gasoline price shocks. The further surge in gasoline prices we hypothesized would double that impact, raising inflation expectations by as much as 1.2 percentage points in December 2021, before gradually dropping off. Unlike headline inflation, one-year inflation expectations remain somewhat elevated throughout 2022 and even in 2023. In contrast, the response of 5-year inflation expectations is subdued. Figure 6 shows a modest peak increase of 0.2 percentage points in early 2022, which only slowly dissipates thereafter.

Table 2 summarizes the main results by year. Consistent with the evidence in Figures 3 and 4, Table 2 suggests that fears that further oil price increases to \$100 in the winter of 2021/22 would trigger an era of prolonged inflation are not supported by the data. After the initial sizable impact of 3 percentage points on annual headline CPI inflation in 2021, the impact of gasoline price shocks falls to 0.4 percentage points in 2022 and completely vanishes by 2023, illustrating that gasoline price shocks have no persistent effect on U.S. headline CPI inflation. Whereas the price level remains elevated, its rate of growth returns to

unstable (see Kilian and Lütkepohl 2017). For example, the stability of the structural model is in doubt when implementing a scenario requires structural shocks that are larger in magnitude than historical structural shocks. Likewise, long sequences of shocks of the same sign under the scenario may cause agents to change their behavior, causing the structural model coefficients to drift. Plots of the historical and hypothetical gasoline price shocks suggest that this critique is not a concern for our analysis.

zero rather quickly. For core CPI inflation the initial impact is reduced to 0.5 percentage points and drops to 0.4 percentage points in 2022, before declining to 0.3 percentage points in 2023. Although there is evidence that the hypothesized temporary oil price surge would raise one-year inflation expectations by 0.8 percentage points in 2022, indicating a more persistent effect on inflation expectations, any effect this may have on observed inflation is already incorporated in the estimated inflation response. The corresponding increase in 5-year inflation expectations of 0.2 percentage points in 2022 and 0.1 percentage points in 2023 is negligible, in any case.

4. Empirical Analysis of PCE Inflation

Model (2) replaces CPI headline inflation in model (1) by PCE headline inflation and uses the trimmed mean of PCE inflation developed at the Federal Reserve Bank of Dallas as the measure of core PCE inflation (see Dolmas and Koenig 2019). The trimmed mean measure is more robust than the PCE inflation measure excluding food and energy in that it controls for outliers in all inflation components rather than just food and energy, which is particularly important during the pandemic recession. It can be shown that replacing the inflation measures in model (1) leaves the results for the inflation expectations largely unaffected, so we concentrate on the results for headline PCE inflation and for the trimmed mean in this section.

Figure 8 highlights that headline PCE inflation is noticeably less responsive to gasoline price shocks than headline CPI inflation. The impact response is only 1.5 percentage points on an annualized basis, compared with more than 2 percentage points in Figure 2. This difference mainly reflects the lower share of gasoline in the PCE index. The general pattern is the same, however. Unlike the response of core inflation in Figure 2, the positive response of the trimmed mean inflation rate in Figure 8 is precisely estimated for the first two months. Overall, the response is more muted and positive at all horizons. The responses of inflation

expectations are generally similar to those in Figure 2.

Table 3 shows that gasoline price shocks, on average, explain only 55% of the variability in headline PCE inflation, compared with 63% for headline CPI inflation, indicating again that the PCE inflation rate appears more robust to gasoline price shocks. The reverse is true when focusing on the core inflation measures. 14% of the variability in the trimmed mean PCE inflation rate is explained by gasoline price shocks compared with only 7% for core CPI inflation in Table 1. Virtually identical shares are obtained for the inflation expectations measures.

Figure 9 shows a much more muted response of headline PCE inflation to gasoline price shocks in early 2020, with a trough of -6 percentage points compared to -9 percentage points in Figure 3, and peaks of 4 percentage points each in early and late 2021, compared with 5 and 6 percentage points, respectively, in Figure 3. This impression is confirmed in Table 2, which shows an impact of only 1.8 percentage points in 2021, 0.4 percentage points in 2022, and 0.1 percentage points in 2023. Clearly, users of headline PCE inflation would be less concerned with the \$100 oil scenario than users of the headline CPI inflation rate.

The results for the trimmed mean PCE inflation rate in Figure 10 also differ substantially from those for core CPI inflation in Figure 4. Whereas the magnitude of the decline in 2020 with 0.8 percentage points is similar, the maximum effect of 0.4 percentage points in early 2021 and 0.7 percentage points at the end of 2021 is substantially smaller than for core CPI inflation, even though we start at a higher base level in Figure 10. Nevertheless, the impact on annual trimmed mean PCE inflation in 2022 and 2023 in Table 2 is broadly similar to that for core CPI inflation. The main difference is that the effect on trimmed mean inflation is somewhat smaller and less persistent. Additional analysis based on replacing the trimmed mean inflation rate in model (2) by core PCE inflation indicates that the impact on annual inflation in the core PCE (defined as the PCE excluding food and energy) would be

0.3 percentage points in 2021, 0.4 percentage points in 2022, and 0.1 percentage points in 2023.

5. Implications for Year-Over-Year Inflation Rates

Whereas our analysis has been based on monthly observations, much of the policy debate is concerned with the evolution of year-over-year changes in the price level. This distinction is important because measuring inflation as a trailing 12-month moving average may affect the duration of the deflationary and inflationary effects of gasoline price shocks, their magnitude and their timing.

As Figure 11 shows, by this metric, gasoline price shocks caused a sustained decline in headline CPI inflation in 2020, which was overcome only in the second quarter of 2021.

Under the scenario, the peak effect of gasoline price shocks on year-over-year headline CPI inflation is only 3 percentage points in late 2021 (compared with 5.7 percentage points in Figure 3 for the monthly rate). However, the inflationary effects of the hypothesized gasoline price shocks by construction decline much more slowly in 2022 than in Figure 1.

Qualitatively similar results hold for headline PCE inflation, except at a lower level. The peak effect of higher gasoline prices under the scenario is reduced from 3.6 percentage points, year over year, to 1.8 percentage points. By comparison, the effect on year-over-year core CPI inflation, core PCE inflation and trimmed mean PCE inflation at the end of 2022 reaches 0.4, 0.4 and 0.2 percentage points, respectively, before gradually declining to zero in 2023, at which point they actually exceed headline inflation.

6. Concluding Remarks

In this paper, we presented simple tools that allow researchers to understand the impact of oil price fluctuations on inflation and inflation expectations, both based on historical data and under hypothetical scenarios about the future evolution of the price of crude oil. The methods discussed in this paper are of general interest to central bankers and macroeconomists.

Recently, even more aggressive oil price scenarios have been advanced. For example, the Bank of America is now predicting that the price of Brent crude oil will reach \$120 a barrel by June 2022, well above the scenario we considered. It would be straightforward to examine the implications of such more extreme scenarios using the tools we employed in this paper. While we have analyzed the impact of oil price scenarios from the point of view of the United States, which simplifies the analysis because oil is traded in U.S. dollars, our analysis could be easily extended to other countries with the important difference that the oil price under a given scenario would have to be expressed in the domestic currency of those countries first, before computing the implied path of gasoline price inflation.

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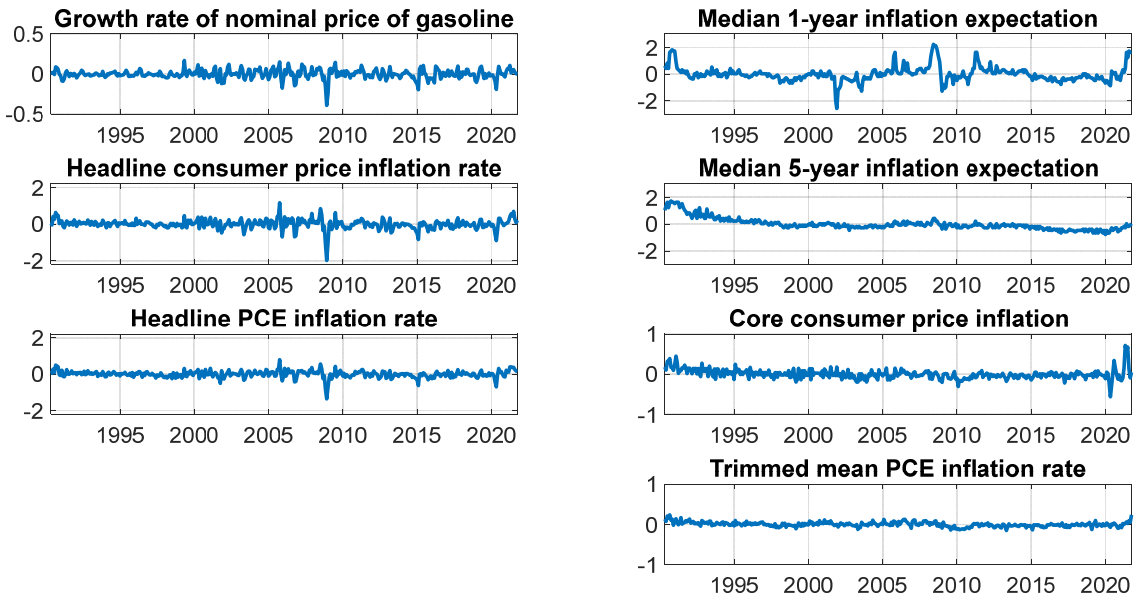
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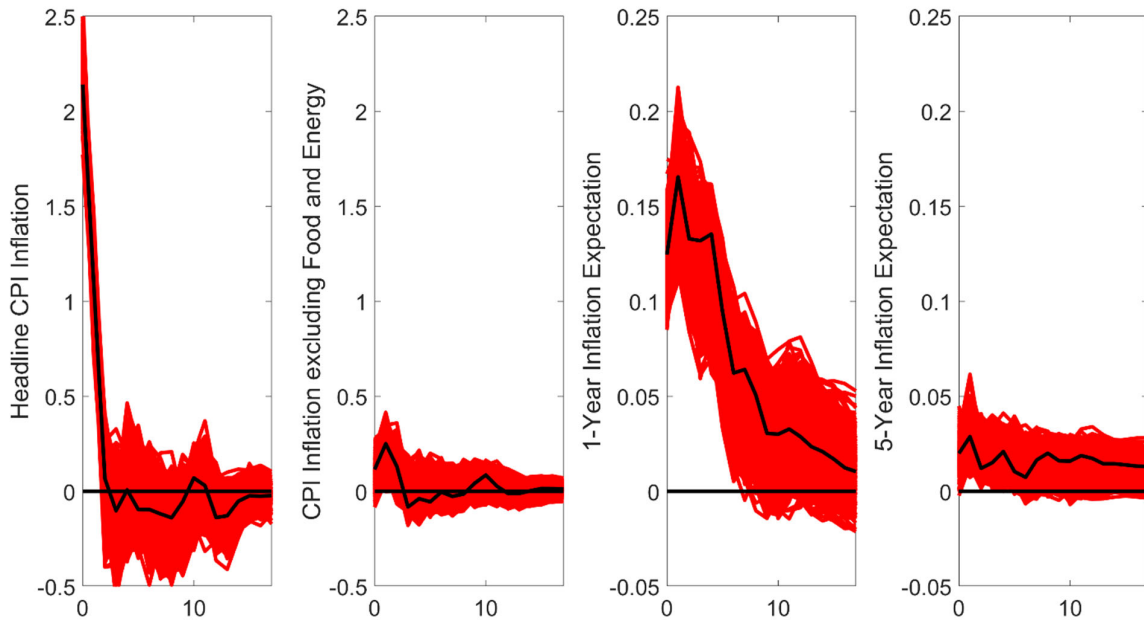
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Figure 1: Indicators used in the VAR analysis, 1990.4-2021.9



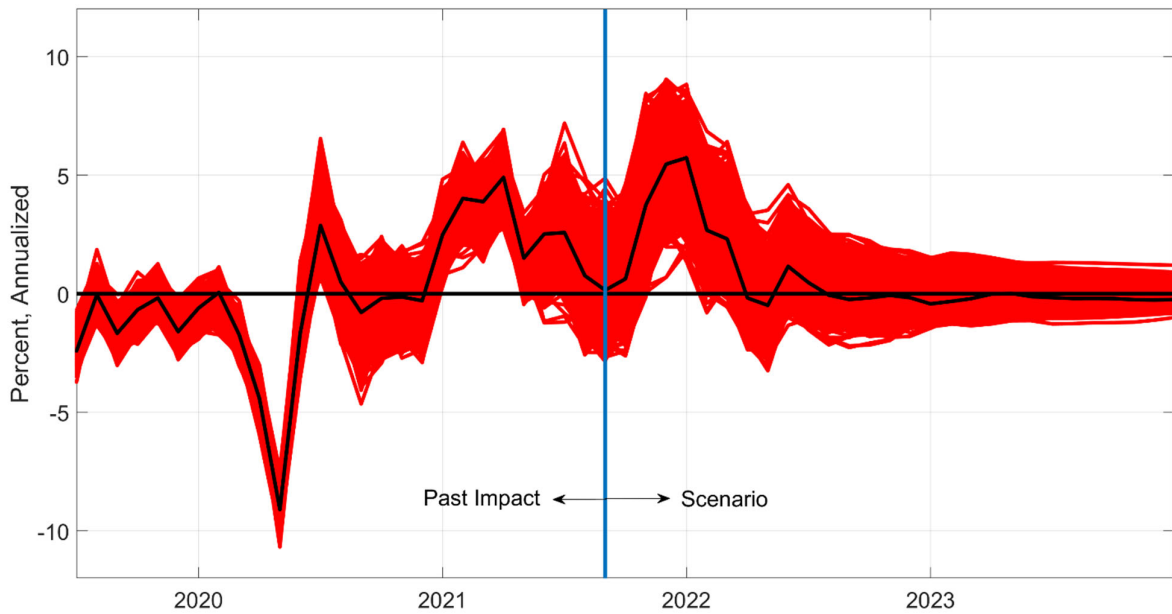
NOTES: All data have been demeaned and expressed in percentage points.

Figure 2: Estimated responses to gasoline price shock in model (1), 1990.4-2021.9



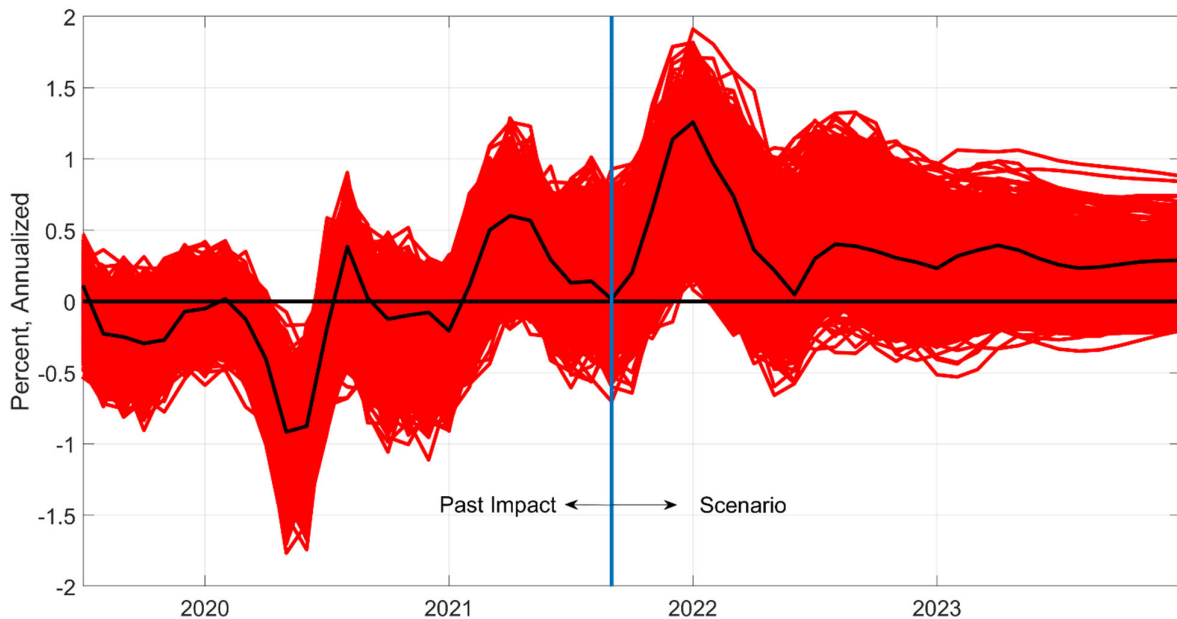
NOTES: The core and headline inflation rates have been annualized. The set of impulse responses shown in black is obtained by minimizing the absolute loss function in expectation over the set of admissible structural models, as discussed in Inoue and Kilian (2021). The responses in the corresponding 68% joint credible set are shown in a lighter shade.

Figure 3: Monthly headline CPI inflation caused by gasoline price shocks, 2019.6-2023.12



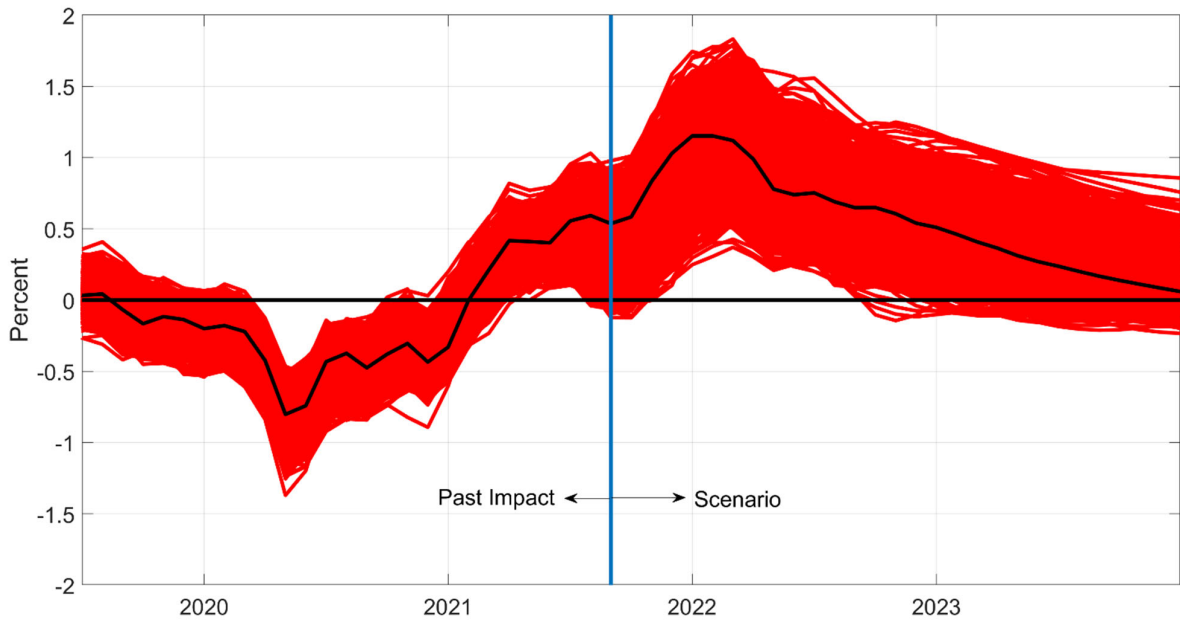
NOTES: Authors' computations based on estimated model (1). The expected path is shown as the black line. The other lines capture the uncertainty about this path based on an approximation to the 68% joint credible set.

Figure 4: Monthly core CPI inflation caused by gasoline price shocks, 2019.6-2023.12



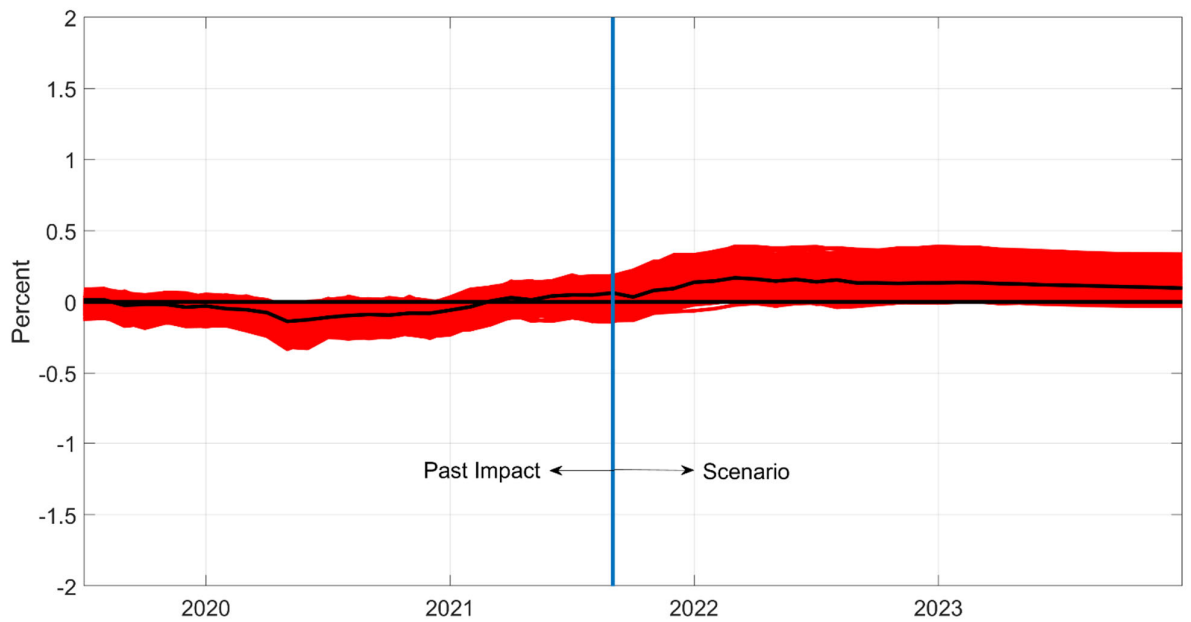
NOTES: See Figure 3.

Figure 5: 1-Year household inflation expectation caused by gasoline price shocks, 2019.6-2023.12



NOTES: See Figure 3.

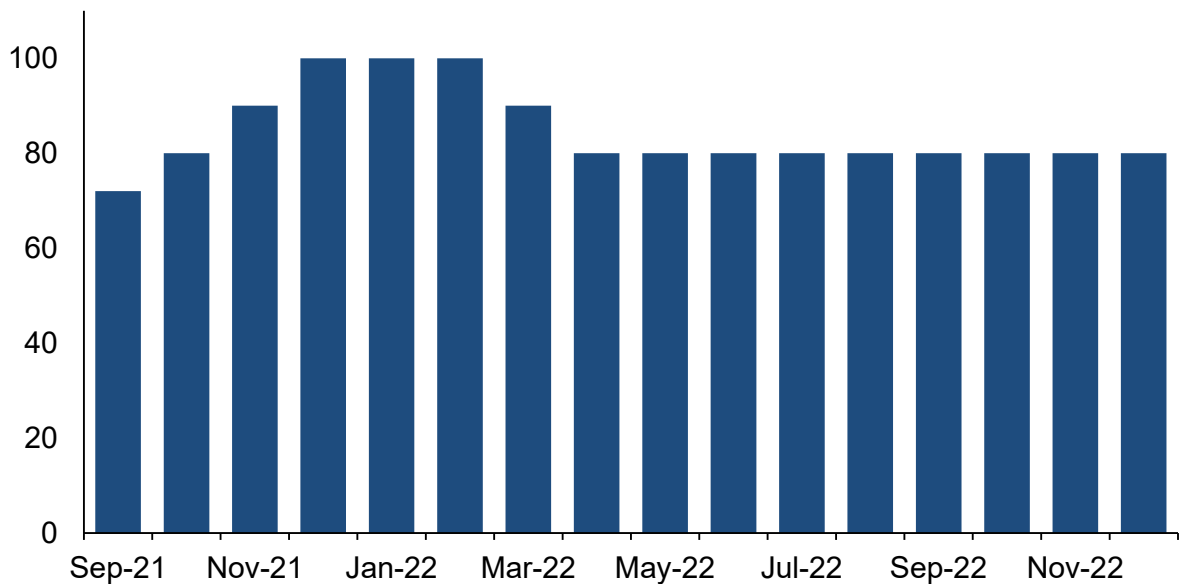
Figure 6: 5-Year household inflation expectation caused by gasoline price shocks, 2019.6-2023.12



NOTES: See Figure 3.

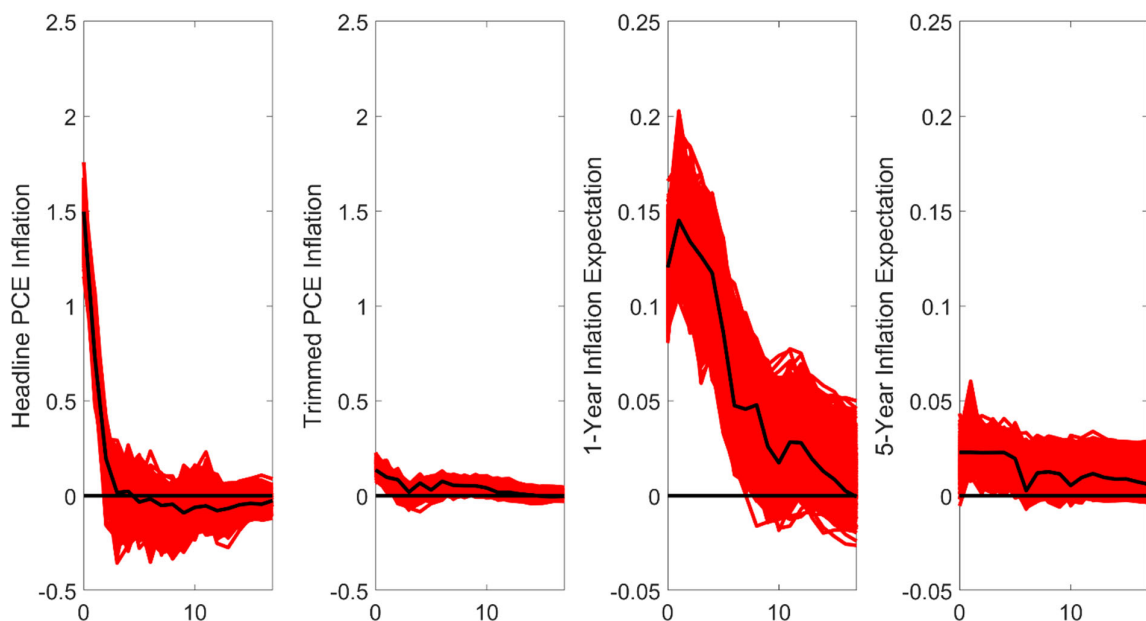
Figure 7: The path of the WTI price of crude oil under the \$100 oil scenario

Dollar/Barrel



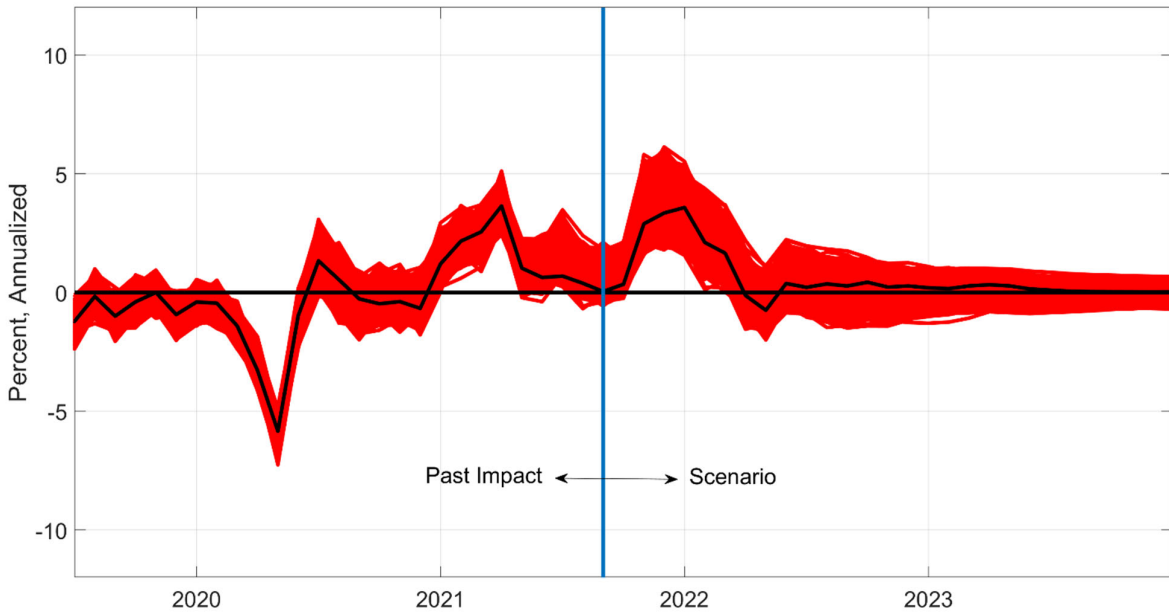
NOTES: The September 2021 observation is included as a benchmark. Under the scenario, the oil price remains at \$80 until December 2023. The prices beyond December 2022 are not included above to improve the readability of the plot.

Figure 8: Estimated responses to gasoline price shock in model (2), 1990.4-2021.9



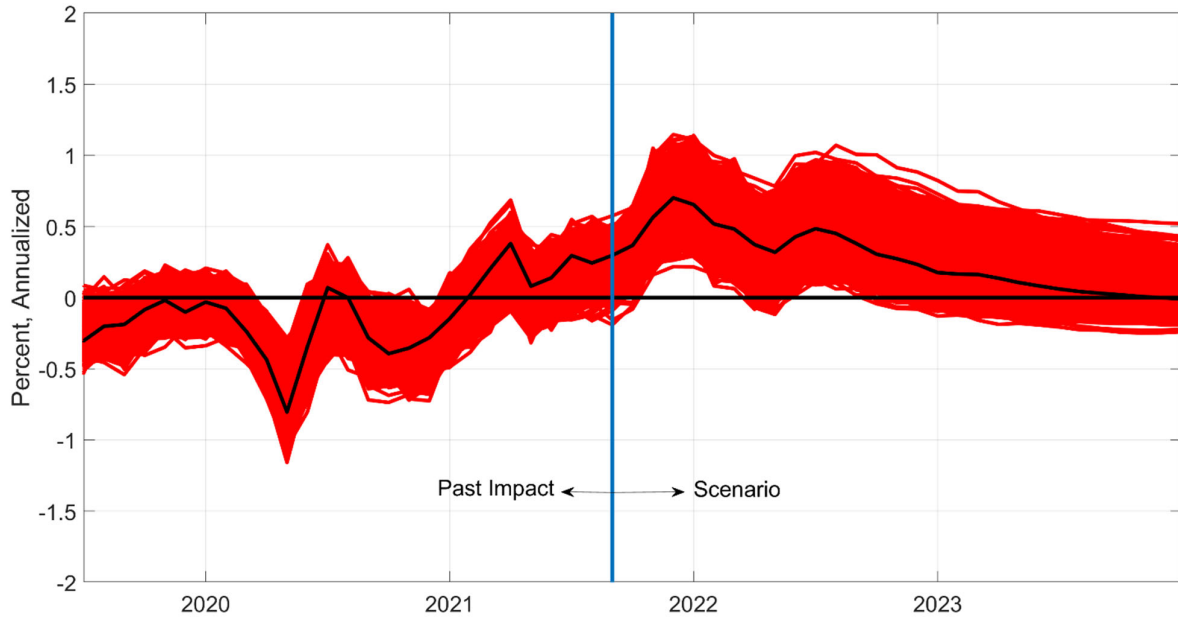
NOTES: The trimmed mean and headline inflation rates have been annualized. The set of impulse responses shown in black is obtained by minimizing the absolute loss function in expectation over the set of admissible structural models, as discussed in Inoue and Kilian (2021). The responses in the corresponding 68% joint credible set are shown in a lighter shade.

Figure 9: Monthly headline PCE inflation caused by gasoline price shocks, 2019.6-2023.12



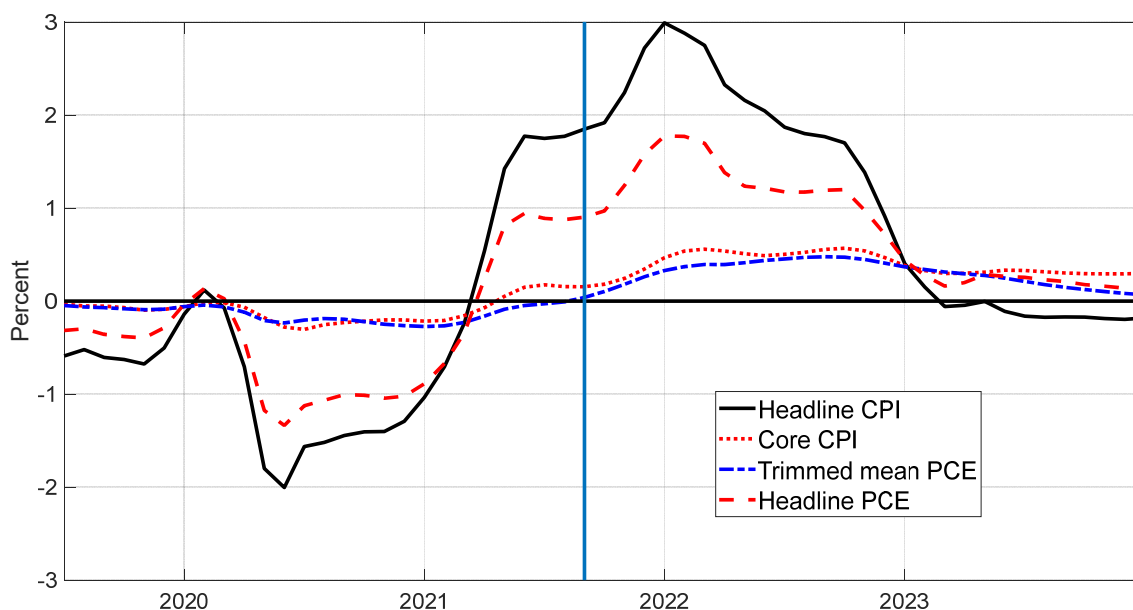
NOTES: Authors' computations based on estimated model (2). The expected path is shown as the black line. The other lines capture the uncertainty about this path based on an approximation to the 68% joint credible set.

Figure 10: Monthly trimmed mean PCE inflation caused by gasoline price shocks, 2019.6-2023.12



NOTES: See Figure 9.

Figure 11: Year-over-year inflationary effects of gasoline price shocks, 2019.6-2023.12



NOTES: Estimates based on models (1) and (2). All results shown are based on 12-month trailing averages of the monthly Bayes estimates in Figures 3, 4, 9 and 10.

Table 1: The contribution of gasoline price shocks to the variability in inflation and inflation expectations

Variables in model (1)	Percent share of variance explained
Headline CPI Inflation	62.9 [59.5, 66.4]
CPI Inflation excluding Food and Energy	6.9 [4.1, 9.8]
1-Year Inflation Expectation	37.5 [30.7, 44.3]
5-Year Inflation Expectation	14.3 [7.6, 21.1]

NOTES: Authors' computations based on model (1). 68% error bands in parentheses.

Table 2: Inflationary effects by year under the \$100 oil scenario (Percentage points)

	2021	2022	2023
Annual Headline CPI Inflation ^a	2.99	0.40	-0.18
	[2.42, 3.54]	[0.14, 1.36]	[-0.35, 0.30]
Annual CPI Inflation excluding Food and Energy ^a	0.47	0.38	0.30
	[0.17, 0.57]	[0.14, 0.72]	[0.02, 0.42]
1-Year Inflation Expectation ^a	0.56	0.76	0.23
	[0.32, 0.62]	[0.52, 1.04]	[0.09, 0.54]
5-Year Inflation Expectation ^a	0.05	0.15	0.12
	[-0.02, 0.09]	[0.09, 0.24]	[0.06, 0.22]
Annual Headline PCE Inflation ^b	1.78	0.44	0.12
	[1.85, 2.46]	[0.02, 0.81]	[-0.26, 0.16]
Annual PCE excluding Food and Energy ^c	0.43	0.33	0.09
	[0.25, 0.57]	[0.07, 0.46]	[-0.06, 0.18]
Annual Trimmed Mean PCE Inflation ^b	0.33	0.37	0.07
	[0.17, 0.39]	[0.25, 0.63]	[0.02, 0.33]

^a Based on estimates of model (1). ^b Based on estimates of model (2). ^c Based on estimates obtained when replacing the trimmed mean PCE inflation in model (2) by core PCE inflation. NOTES: Authors' computations based on estimates of models (1) and (2). The table shows the average value of the estimated path of each variable over the 12 months of a given year. The corresponding 68% error bands are shown in parentheses.

Table 3: The contribution of gasoline price shocks to the variability in inflation and inflation expectations

Variables in model (2)	Percent share of variance explained
Headline PCE Inflation	54.8
	[51.2, 58.5]
Trimmed Mean PCE Inflation	14.6
	[10.1, 19.0]
1-Year Inflation Expectation	37.0
	[30.4, 43.7]
5-Year Inflation Expectation	14.3
	[7.7, 21.0]

NOTES: Authors' computations based on model (2). 68% error bands in parentheses.

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