Inflation dynamics and quantitative easing

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ABSTRACT

The impact of Quantitative Easing (QE) is assessed using *ex post* Federal Reserve balance sheet data and controlling for fiscal policy, conventional monetary policy, financial friction, oil price, aggregate demand and aggregate supply shocks. The empirical structural VAR embeds the idea of a four-equation New Keynesian theoretical framework, allowing us to not only measure the effect of a QE shock on inflation, but also its interaction with the abovementioned theoretically-consistent third variables. Some key results are: (i) reversing QE will likely have a small gain in disinflation but much larger loss of GDP growth; (ii) in order of magnitude, the leading factors driving inflation in the COVID-19 era are supply, demand, fiscal and QE shocks; (iii) while the order of magnitude for the overall sample is supply, demand, fiscal and oil shocks; and (iv) inflation takes a long time to converge or transition following a shock.

KEY WORDS: quantitative easing, inflation, COVID-19, fiscal deficit, cyclical growth

1. Introduction

Large-Scale Asset Purchases (LSAP), also known as quantitative easing (QE), influence the macroeconomy through asset prices which themselves respond via a signaling channel, portfolio rebalancing or bank lending channel. Measuring the effects of QE encounters a technical difficulty associated with the zero-lower bound – a situation in which the benchmark policy rate is stuck at zero. Therefore, shocks to the policy rate that are meant for isolating monetary policy interventions become implausible. One work around is to calculate a shadow interest rate that is not restricted by the zero-lower bound (Wu and Xia 2016; Krippner 2013). Studies using the shadow rate to measure QE shocks – particularly in the early stages of the large asset purchases – have uncovered substantial favorable effects on macroeconomic variables – both financial and real (Hara et al. 2020; Wu and Xia 2016).

The approach of the shadow interest rate takes for granted that the Federal Reserve (the Fed) has a single monetary policy instrument, the benchmark federal funds rate, which has to hit two objectives: the output gap (or short-term growth rate) and the rate of inflation relative to an inflation objective of two percent. Tinbergen's rule, however, dictates that the number of objectives of the policy maker cannot exceed the number of policy instruments (Tinbergen 1952). It can be shown theoretically that in

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a world of a single interest rate instrument and two objectives (employment and inflation), the best the central bank can achieve is a linear combination of the two objectives – exactly as the Tinbergen rule suggests (Michl 2007). Moreover, utilizing forward-looking measures on output gap and inflation do not improve the monetary policy efficacy when there is a single interest instrument because of limited ability of policy makers to process the data and know the true probability distribution (De Grauwe and Ji 2022).

Therefore, we explicitly calculate QE shocks from *ex post* or realized data of securities that were purchased by the Fed. In other words, we introduce a second policy instrument that is calculated as the summation of the face value of treasury securities, mortgage-backed securities and agency debt that are held as assets on the Fed's balance sheet. Other event studies have used *ex ante* or desired announcement of purchases, and for a much shorter time period than the focus of this paper (Hesse et al. 2018; Weale and Wieladek 2016). The face value of the aggregated QE assets shows actual realization of asset purchases and therefore the corresponding change in private sector liquidity (Nelson 2013), which will generate portfolio balance adjustments (Goldstein et al. 2018; Christensen and Krogstrup 2018). The *ex post* data also nest the expectation effects of the announcement-based data. Finally, QE must expand the balance sheet of the Fed – an outcome we exploit to measure QE shocks.

Furthermore, recent theoretical works argue that the New Keynesian three-equation model needs a fourth equation which must account for QE (Sims et al. 2022). Motivated by preferred habitat theory, Ellison and Tischbirek (2014) make a similar point by observing that the central bank is better able to stabilize inflation and output if there is a complementary instrument that accounts for Large-Scale Asset Purchases, even when the interest rate is not constrained at the zero-lower bound.

Our structural VAR (SVAR) analysis accounts for both conventional and unconventional monetary policy shocks, as well as aggregate demand and supply shocks along with shocks of other variables that are essential to the systematic aspect of the empirical model. For instance, in keeping with the early work of Sims (1992), we control for anticipatory or endogenous monetary policy reaction by including oil price, which can also account for international shocks. In order to account for possible omitted variable in the systematic part of the SVAR, we include a measure of financial friction and the fiscal balance. QE was conducted during a period of active fiscal expansion, making the coordination between monetary and fiscal policies an important control factor (Allen 2012; Hoffman et al. 2021). These variables, therefore, enable us to isolate the impact of QE (the expansion of the Fed's balance sheet) and conventional monetary policy, as well as the third variables, on inflation. The structural interpretation of the empirical model also enables us to measure the effect of QE, conventional monetary policy and third variables on real GDP growth. In the context of this study, the third variables are fiscal, financial friction, oil, and supply shocks[3].

QE, in response to the subprime crisis and COVID-19 pandemic, has had a substantial effect in stimulating short-term economic growth while easing financial frictions. QE also had a positive effect on inflation. So too has been a fiscal expansion. There is significant persistence or stickiness in the US inflation data. A supply, aggregate demand, fiscal or oil shock engenders inflation adjustment that takes more than three years to converge to pre-shock equilibrium or a new one. The latter has implication for the popular debate surrounding transitory or non-transitory inflation. We do not know whether inflation will return to its pre-pandemic equilibrium or converge to a higher one. Nevertheless, in spite of slow

[3] The primary focus of the paper is an assessment of QE and inflation. However, to effectively study this connection, we have to account for the pre-QE time period, as well as other important third shocks taking place during the pre- and pos-QE era.

convergence, we conclude that inflation is transitory even if it transitions to a higher equilibrium relative to the pre-pandemic average. Finally, our estimates suggest that unwinding QE will likely produce a small gain in terms of disinflation, but a much larger decrease in economic growth.

The rest of the paper is organized as follows. Section 2 gives a preliminary account of the relationship between QE and net worth of firms and households. Section 3 provides a discussion of the variables (their sources and definition) and the SVAR. Section 4 provides a detailed discussion of the results. Section 5 concludes.

2. Private Net Worth and QE: A Brief Note

The net worth of firms and households is central to the transmission mechanism of conventional monetary policy (Mishkin 1995). The same idea should hold in an environment of unconventional policy. For example, QE was known to stimulate stock prices in the United States (Al-Jassar and Moosa 2019). Higher stock prices would expand households' and firms' net worth, thereby easing the financial frictions (adverse selection and moral hazard) restricting credit allocation to these two sectors of the economy. Moreover, the higher stock prices could transmit monetary policy effects to the real sector through a Tobin's q mechanism.

The simple scatter plots show the association between household and firms' net worth (first difference) and a change in the Fed's QE assets. Panel A and B respectively indicate how the net worth of the two sectors is correlated with a change in the two main QE assets: treasury securities and mortgage-backed securities. In general, a positive change in the purchase of federal debt (treasuries) was associated with a noticeable positive change in the net worth of both households and firms[4].

On the other hand, the scatter plots showing the association between the Fed's purchase of mortgage-backed securities and the sectoral net worth is mixed. The purchases are associated with a positive change in household net worth, but a flatline for firms' net worth. To some extent, the latter outcome seems sensible. QE would have had a broad-based favorable stabilizing effect on household net worth through the housing market. However, the same policy would have had only a small effect on firms given that housing is a relatively small fraction of total firm production activity, while home ownership is substantially more dispersed among households.

Finally, there is a negative correlation coefficient amounting to −0.503 between the change in household net worth and financial conditions index (a proxy measure of financial friction)[5]. The correlation coefficient index is −0.208 between the change in corporate net worth and financial conditions index. Higher values of the said index indicate tighter financial conditions. The Fed purchase of treasuries and mortgage-backed securities is also negatively related to the financial conditions index, amounting to respectively −0.105 and −0.013.

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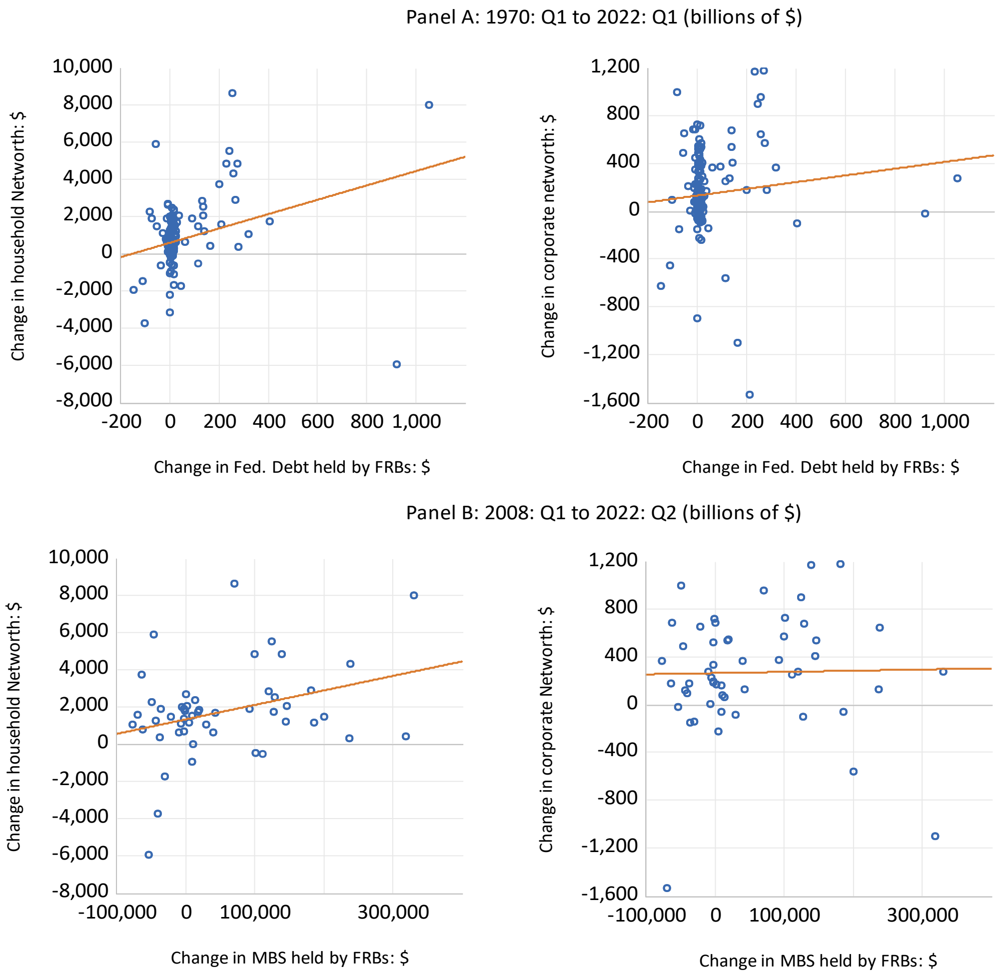
[4] There has been a debate in economics on whether the government's debt represents a net wealth to the private sector. This debate is also applicable in the context of QE: does the purchase of treasury securities by the Fed represent a net wealth to the private sector. A theoretical implication is we should be looking at the present value of the assets purchased, as was done by Weale and Wieladek (2016). However, agents do not have full information and often rely on rules of thumb and limited processing capacity (De Grauwe and Ji 2022). Important for our work is the idea that QE replaces a percentage of the treasuries held by the private sector with outside money liquidity. This produces portfolio rebalancing and real effects.

[5] See Section 3 for a discussion of data sources and definition. Appendix 1 provides the link to all the online data used in this study.

Figure 1 QE assets and household and firm net worth, 1970: Q1 to 2022: Q1



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In summary, the Fed's monetary action in the format of asset purchases is critically connected to household and firm net worth, warranting further investigation on the explicit transmission mechanism of the balance sheet channel. This study contributes to a time-sensitive issue as the Fed is currently administering contractionary policies in response to high inflation since mid-2021. Despite two rounds of consecutive 0.75% increases to the federal funds rate, the total assets held by the Fed is only beginning to decline after peaking at $8.97 trillion in April, 2022.

3. Data and Methodology

The baseline model that examines the effect of conventional monetary policy, demand, and supply shocks, as well as oil and financial shocks on inflation and short-term growth dynamics is based on a structural VAR model consisting of five variables: real output growth (*gdpg*), CPI inflation (*inf*), federal funds rate (*ffr*), financial frictions (*nfc*), and oil price (*oil*). Specifying the oil shock separately allows us to disentangle it from a pure supply shock. In addition, specifying financial friction separately allows us to disentangle its shock from a pure demand shock since this variable enters the Phillips curve in a structural theoretical framework (Sims et al. 2021). The endogenous variables of the baseline model are given by the row vector, eq. (1).

$$X_t^{Base} = (gdpg_t,\ inf_t,\ ffr_t,\ nfc_t,\ oil_t) \tag{1}$$

More specifically, we take the real GDP published quarterly by the Congressional Budget Office and linearly interpolate into monthly data. To test for the validity of the interpolated results, we also estimate the real monthly GDP using a total incomes approach that incorporates wages, corporate profit, interest, rent and proprietor income[7]. The correlation between GDP measured using these two methods is 0.999, providing strong support for our interpolated estimate. Real GDP growth is obtained by calculating the monthly year-on-year percentage growth rates. Appendix 1 shows the link to all the data used in this paper.

Our inflation variable is measured using the year-on-year percentage change of the Consumer Price Index (CPI) published monthly by the Bureau of Labor Statistics. Interest rate is measured using the federal funds rate published by the Board of Governors of the Federal Reserve System. Oil price is the West Texas Intermediate crude oil price measured in US dollars per barrel. The baseline model uses monthly data and covers the period from January 1971 to January 2022, with a total of 613 observations for each variable.

The study of the role of financial frictions in the transmission mechanism of economic shocks has been studied extensively, pioneered by Kiyotaki and Moore (1997) and Bernanke et al. (1999). We take the Chicago Fed's national financial conditions index (NFC) to measure the US financial conditions in the money market, debt and equity markets, as well as the traditional and shadow banking systems. Tightened financial conditions are characterized by positive values of NFC, while negative values represent loosening conditions in the markets.

[7] Monthly data on the various income series are available, except for corporate profit that is available at the quarterly frequency. Therefore, the monthly profit series was calculated using a linear interpolation method and added to the other monthly data to calculate the monthly aggregate income. The latter series was then deflated using the GDP deflator.

QE model

We introduce a new variable, *fed,* to explicitly account for the balance sheet effect of the Federal Reserve. This variable is calculated by summing the monthly mortgage-backed securities, treasury securities and agency debt held by the Fed. The QE model covers the period from March 2008 to January 2022, which zooms in on the global financial recession when the Fed purchased substantial quantities of the securities mentioned earlier. We chose March 2008 as the start of the QE period when the Fed first initiated the purchasing of agency debt to address liquidity pressures in the market (FOMC 2008). This model allows us to comprehensively examine monetary shocks by incorporating both the interest rate and balance sheet effects. The QE model is specified by the row vector, eq. (2).

$$X_t^{QE} = (gdpg_t,\ inf_t,\ ffr_t,\ fed_t,\ nfc_t,\ oil_t) \tag{2}$$

Fiscal-baseline and fiscal-QE models

Congress and the White House implemented expansionary fiscal policies during the period of QE, motivating us to examine the interaction of fiscal and unconventional monetary policies. We introduce the realized fiscal balance (*fb*) to explicitly incorporate the US fiscal policy. The realized fiscal balance reflects previous policy decisions undertaken by Congress and the White House. The Treasury Department produces monthly data on federal surpluses and deficits, which are available after October, 1980. The modified baseline model covers the period from January 1981 to July 2022 with a total of 500 observations, characterized by eq. (3).

$$X_t^{Fiscal-base} = \left(fb_t,\ gdpg_t,\ inf_t,\ ffr_t,\ nfc_t,\ oil_t\right) \tag{3}$$

The fiscal-QE model has the following variables.

$$X_t^{Fiscal-QE} = \left(fb_t,\ gdpg_t,\ inf_t,\ ffr_t,\ fed_t,\ nfc_t,\ oil_t\right) \tag{4}$$

Table 1 Summary statistics

Variable Name	Notation	Mean	Std. Dev	Obs.	Min.	Max.
Real GDP growth (%)	*gdpg*	2.62	2.25	613	-9.99	10.89
Inflation (%)	inf	3.93	2.95	613	-2.00	14.60
Federal funds rate (%)	*ffr*	4.92	3.98	613	0.05	19.10
National financial conditions index	*Nfc*	0.0005	1.00	613	-1.05	4.86
Oil price (US$)	oil	37.36	27.55	613	3.56	133.93
Fed's QE assets (Billions of $)	*Fed*	1,467.1	530.0	167	476.4	2,657.7
Fiscal balance (Billions of $)	*Fb*	-41.34	95.90	493	-864.07	214.26

The summary of statistics is reported in Table 1. In addition, standard Phillips-Perron and Augmented Dickey Fuller tests are performed on all variables. Results show that the output growth, inflation, national financial confidence index, fiscal balance and federal funds rate are stationary at the level, while oil price and the Fed's total QE assets are stationary at the first-difference.

Identification

The baseline SVAR model is estimated using monthly data from 1971:01 to 2022:07, with a total of 620 observations. The structural VAR representation is given by eq. (5).

$$B_0 X_t = \beta + \sum_{i=1}^{n} B_i X_{t-i} + \varepsilon_t \tag{5}$$

Here, X_t is a column vector of *k* endogenous variables defined earlier. B_0 captures the contemporaneous effects in a $k \times k$ matrix, and β is a vector of constant terms. B_i represent the $k \times k$ autoregressive coefficient matrices and *n* is the optimal lag length. Equation 6 indicates the Cholesky ordering of the contemporaneous exogeneity of the structural shocks. The reduced-form errors e_t can be decomposed as a *k* x 1 vector of serially and mutually uncorrelated structural innovations according to $e_t = B_0^{-1}\varepsilon_t$, requiring *k* × *(k – 1)/2* restrictions to fully identify the model. This is indicated by eq. (6).

$$e_t = \begin{pmatrix} e_t^{gdpg} \\ e_t^{inf} \\ e_t^{ffr} \\ e_t^{nfc} \\ e_t^{oil} \end{pmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{demand\ shock} \\ \varepsilon_t^{supply\ shock} \\ \varepsilon_t^{interest\ rate\ shock} \\ \varepsilon_t^{financial\ shock} \\ \varepsilon_t^{oil\ price\ shock} \end{pmatrix} \tag{6}$$

In the QE model, we put the Fed's balance sheet variable immediately after the federal funds rates. This is done in order to reflect the notion of the zero-lower bound. The idea is, contemporaneously, a QE shock cannot influence the interest rate because the rate is stuck at the zero-lower bound. However, the Fed targets the interest rate first and then adjusts its assets in line with liquidity in the overnight market. Moreover, this specification allows us to have two instruments in order to meet the growth and inflation objectives. This is shown by equation (7).

$$e_t = \begin{pmatrix} e_t^{gdpg} \\ e_t^{inf} \\ e_t^{ffr} \\ e_t^{fed} \\ e_t^{nfc} \\ e_t^{oil} \end{pmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & b_{66} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{demand\ shock} \\ \varepsilon_t^{supply\ shock} \\ \varepsilon_t^{interest\ rate\ shock} \\ \varepsilon_t^{balance\ sheet\ shock} \\ \varepsilon_t^{financial\ shock} \\ \varepsilon_t^{oil\ price\ shock} \end{pmatrix} \tag{7}$$

Business cycle theory tells us that only shocks to demand can influence output contemporaneously. Consistent with the idea that the federal funds rate reacts to economic conditions and following Stock and Watson (2001) and Kim and Roubini (2000), we assume that the Fed responds to contemporaneous changes in output and inflation. Moreover, detailed sensitivity analyses ordering the policy rate first and last in a four-variable VAR (with shocks for demand, supply, wage bill and monetary policy) obtain almost identical results (Cucciniello et al. 2022).

Financial frictions in the market are assumed to respond to the Fed's decision contemporaneously. Moreover, a shock to financial friction affects the real economy, as well as growth and inflation with a lag. Our identification strategy follows Kim and Roubini (2000) to include oil price as proxy for negative and inflationary supply shocks in the world.

We consider the fact that the oil price is affected by both aggregate demand and supply shocks emanating from the United States. The oil price also reflects global demand and supply shocks, as well as other factors unique to the oil market itself. Therefore, after considering the deep analysis of this topic by Kilian (2009), we assume the oil price is most endogenous, contemporaneously. The essential idea is the oil price is very sensitive to news regarding the state of the US economy. However, an oil price shock today will take some time to influence the real sector, prices and financial conditions.

Finally, fiscal policy is assumed to be exogenous contemporaneously to all the shocks in the system, including demand and supply shocks. The realized overall fiscal balance is dependent on the political process, as well as political calculations of Congress and the White House, and not necessarily rational economic calculations. Moreover, the current-period fiscal balance reflects previous fiscal policies (tax and spending measures) by Congress and the White House. The shocks in the final fiscal-QE model is identified as follows.

Nevertheless, monetary policy could influence the interest cost of the federal government's debt when the Fed adjusts the interest rate. In such an event, the shock term ($\varepsilon_t^{fiscal\ shock}$) is ordered after the monetary shock ($\varepsilon_t^{interest\ rate\ shock}$). The latter model is also estimated for the purpose of robustness, the result of which is reported in the Appendix.

$$e_t = \begin{pmatrix} e_t^{fb} \\ e_t^{gdpg} \\ e_t^{inf} \\ e_t^{ffr} \\ e_t^{fed} \\ e_t^{nfc} \\ e_t^{oil} \end{pmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & 0 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} & 0 & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & b_{66} & 0 \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & b_{77} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{fiscal\ shock} \\ \varepsilon_t^{demand\ shock} \\ \varepsilon_t^{supply\ shock} \\ \varepsilon_t^{interest\ rate\ shock} \\ \varepsilon_t^{balance\ sheet\ shock} \\ \varepsilon_t^{financial\ shock} \\ \varepsilon_t^{oil\ price\ shock} \end{pmatrix} \tag{8}$$

Furthermore, one might ask of us to justify our preference for the overall fiscal balance instead of the primary balance. The interest the federal government pays on its debt represents a source of income for private economic agents. In a non-Ricardian world, the overall fiscal balance is preferable when studying the impact of fiscal policy on inflation and real growth.

Finally, it is well known that monetary policy shocks have strong effects on exchange rate dynamics (Kim and Roubini 2000). However, we do not pursue the exchange rate channel for two reasons. Firstly, during preliminary testing we found negligible statistical evidence from exchange rate to output and inflation in the United States. Secondly, one factor explaining the latter outcome likely stems from the currency invoicing regime: owing to the outsized role of the dollar in invoicing of import and export, there is a negligible effect of exchange rate on US inflation (Gopinath et al. 2010, Matschke and Sattiraju 2022). The latter scenario, however, would not be true for highly open economies, such as developing and emerging market economies.

4. Results and Discussion

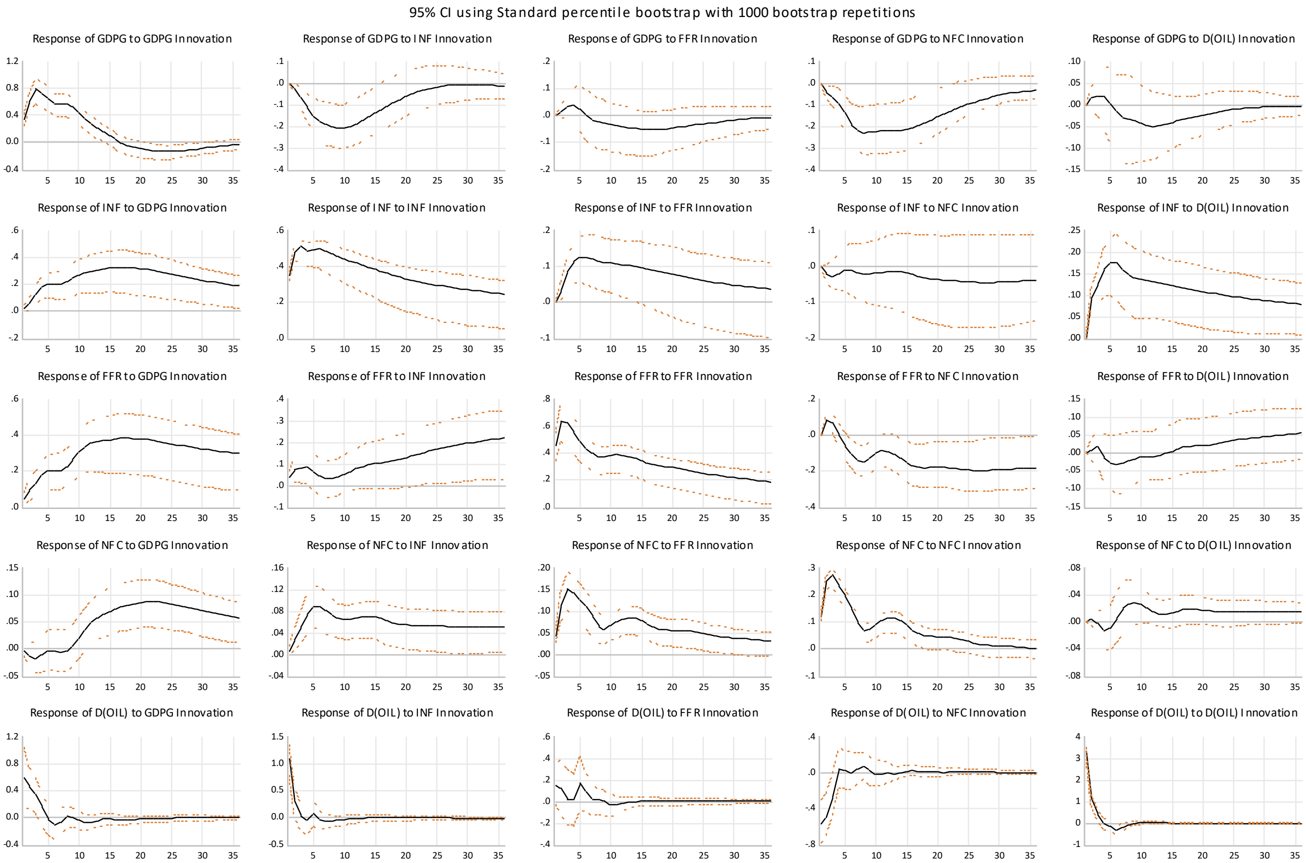
We first present the results for the baseline model without fiscal and QE shocks. The model was estimated using monthly data from 1971: 01 to 2022: 07 and it is estimated with five lags as indicated by the Schwartz Information Criterion (SIC). Given the monthly data, the baseline model is also estimated with 12 lags. The results of the latter 12-lag baseline model – reported in Appendix 2, Figure 1A – are virtually identical to the 5-lag model discussed herein. Finally, all roots of the characteristic polynomial fall within the unit circle, thus suggesting a stable VAR. We also present the 95 percent bootstrap standard error bands.

The impulse response functions (IRFs) for 36 forecast months are largely consistent with theory. The demand shock has a noticeable positive effect on short-term economic growth. Note that the vertical axes of the first row in Figure 2 are indicating percentages. Economic growth contracts for almost 29 months following a supply shock. This means that a supply shock has a longer contractionary effect than the simulative effect of a positive demand shock. Growth contracts after six months following a tightening (increase) of the policy interest rate. A financial shock has a relatively long negative effect on GDP growth, a result consistent with theory and other studies (Jermann and Quadrini 2012). It takes over 36 months, on average, for the effect of the adverse financial shock (positive increase in NFC) on growth to dissipate to zero. A positive oil shock contracts GDP growth, albeit with wider error bands, after six months.

The inflation response and dynamic adjustments are also consistent with theory and previous studies. The vertical axes of the second row in Figure 2 are also showing percentages. The favorable demand shock has positive effect on inflation – the effect of which takes over 36 months to converge to zero. Consistent with theory, the adverse supply shock also increases inflation, which also takes over 36 months to return to zero. The oil price shock, too has a sustained adverse effect on growth for over 36 months. In terms of size, the supply effect exerts the strongest impact on US inflation, followed by demand and oil shocks. Interestingly, we also found evidence of the ‘price puzzle’ (also known as Gibson’s paradox) or anticipatory changes in the federal funds rate to inflation. The latter topic has been extensively studied in the literature using VAR methods (Cucciniello 2022; Estrella 2015; Sims 1992).

A positive demand shock eases financial friction for approximately eight months, after which time financial conditions tighten (see row 5 of Figure 2). A supply shock elicits a positive response (tightening) of financial conditions, which continues in that state for at least 36 months. Therefore, a supply shock – rising inflation and lower growth – has a more adverse effect on financial conditions compared with a positive demand shock. Tightening conventional monetary policy, as expected, increases the financial friction (or make financial conditions tighter). The latter result is expected given the literature on the balance-sheet channel of monetary transmission mechanism (Mishkin 1995). The oil price shock temporarily eases financial friction, but there is a deterioration from forecast period six. Initially, the higher oil price elicits larger profits and production from US oil companies. This reduces their borrowing constraint and therefore eases the financial friction. However, from month six household incomes are affected and therefore financial conditions tighten.

Figure 2 Impulse response of the baseline model without fiscal shock



Finally, the positive demand shock produces a temporary increase in the price of oil (row 5 of Figure 2). The change in the oil price falls to zero from the sixth forecast month given the demand shock. Interestingly, the supply shock – which previously contracted GDP growth – has an even shorter temporary positive effect. On the surface, this seems like an anomaly given that the supply shock is associated with contraction of economic growth. One possible explanation for this is portfolio adjustment in financial markets: higher inflation makes stocks and bonds less desirable and therefore improves the relative desirability of commodities like oil in the short term. The monetary policy shock also causes stocks to be revalued downward, thus making commodities (including oil) more desirable for a short period of time. However, the magnitudes are fairly small given that vertical axis is measuring dollars per barrel. The positive shock to financial friction has an immediate negative effect on the price of oil. This time the magnitude is much larger, albeit short lived up to five months. The latter result indicates that oil trade and speculation depend substantially on credit lines.

Fiscal-baseline model

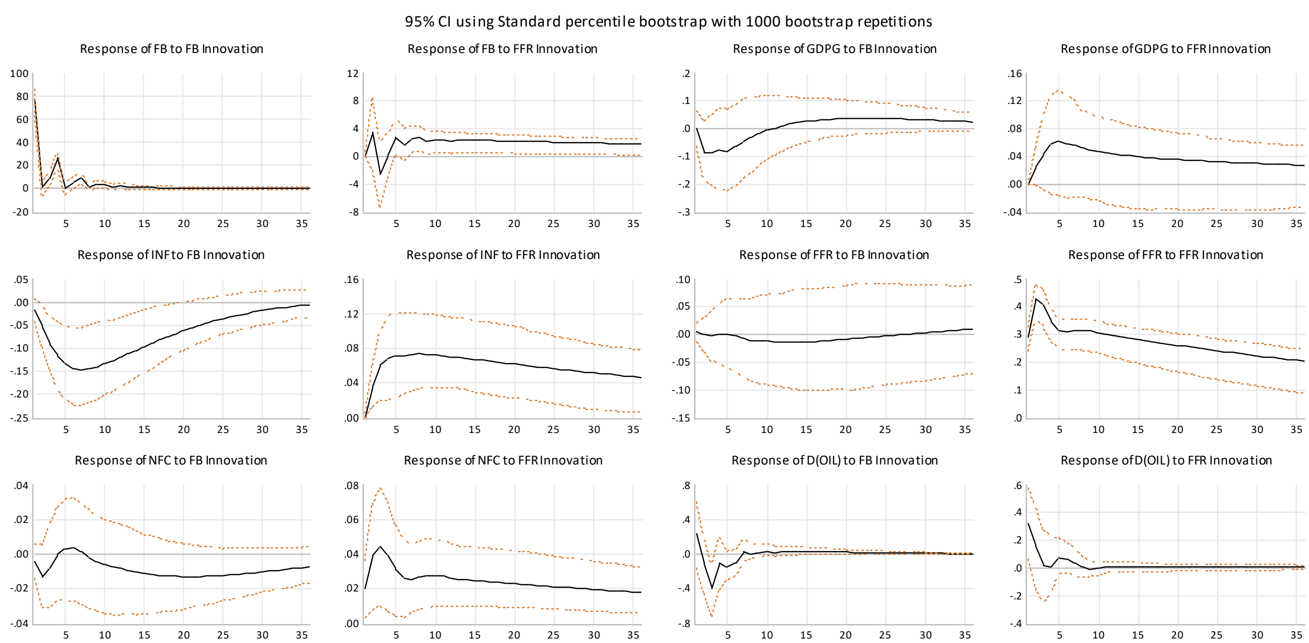
This model is estimated over the period 1981: 01 to 2022: 07. The time period is truncated because the monthly fiscal balance is available from 1981: January. The SIC indicates that three lags are best for this model. The model was also re-estimated with a 12-month lag as a rule of thumb. The results are very similar to the model with three lags, as suggested by the SIC. More importantly is the matter of whether the fiscal balance is endogenous to monetary policy through contemporaneous changes in the interest cost of federal debt. Therefore, the fiscal-baseline model is re-estimated to account for this possibility at both three and twelve lags. The results for the 3-lag model is presented in Appendix 2, Figure 2A.

All the roots of the characteristic polynomial fall within the unit circle. Figure 3 only shows the results for two policy interventions: fiscal and monetary shocks. Emphasizing these two shocks show the fiscal-monetary interaction and economize on space. The other shocks engender identical results to Figure 2.

The first and third columns of Figure 3 indicate the IRFs of a fiscal shock. It should be noted that a positive fiscal shock indicates an improvement in the fiscal balance or a contraction of the deficit (fiscal tightening). The rate of inflation falls following a fiscal tightening, which, on average, elicits a deflationary adjustment for approximately 36 months. Conversely, we could say that a fiscal expansion – on average – increases inflation up to 0.15 percent by period seven following a fiscal expansion. Therefore, after considering the estimates from Figures 2 and 3, we can conclude that the inflationary factors in order of importance are: supply, demand, oil, monetary and fiscal shocks.

The first chart in the third column (Figure 3) shows the accompanying GDP growth adjustment following the fiscal shock. The growth rate turns negative for approximately 12 months, after which time there is a small positive growth effect for the rest of the forecast horizon. There is no indication that the Fed's policy rate is influenced by the fiscal tightening; hence, there is no evidence of fiscal dominance. The fiscal tightening has a small initial positive effect on the price of oil. However, the adjustment in the oil price turns negative quickly and stays that way until it reaches zero by the eight-forecast month. Financial friction eases as the fiscal balance moves towards a surplus (row 3, column 1). The latter outturn possibly explains why a fiscal contraction temporarily increases oil price. Easier financial conditions relax credit for speculation in the crude oil market. Another probable explanation is a fiscal contraction reduces the stock of tradable treasury bills and bonds, thus requiring market participants to find alternative investment vehicles such as commodities.

Figure 3 IRFs showing monetary and fiscal shocks: fiscal-baseline model



Confirming robustness of the results, the conventional monetary policy shock produces the same impact response and dynamic adjustments as in Figure 2. Therefore, we will not replicate them in Figure 3. It is interesting, however, to observe the fiscal adjustments following a monetary shock. Although the magnitude is small, just under $3 billion, the monetary tightening is followed by fiscal contraction after the fifth forecast month. This does not imply that Congress and the White are coordinating these fiscal responses. Once the Bill is made into law, the Treasury Department writes the cheques over time, often over several years. The Treasury is aware that when it releases cheque-based liquidity it could influence the federal funds market and targeted interest rate (Meulendyke 1998).

QE model

The QE model without the ex post fiscal balance is first estimated for the period 2008 (March) to 2022 (July). The SIC indicates two lags are appropriate and all the roots of the characteristic polynomial fall within the unit circle. Figure 4 presents various emphasized IRFs, namely the results for two shocks: the QE and financial friction shocks. These were two of the main events of the period under consideration as the interest rate fell to zero. The other shocks produce similar results as in the baseline models; therefore, we will not reproduce them here.

The first column in Figure 4 and first chart in column 3 show the impact response and dynamic adjustments of the endogenous variables following a QE shock (*fed*). On average, at its highest point in the fourth month after a shock, QE adds up to 0.32 percent to real economic growth. The positive growth effect is however relatively short-lived petering out to zero sixteen months later and subsequently transitioning to a negative effect of around –0.05 percent. Overall, this finding suggests that large asset purchases do have a real effect. Multiple rounds of large-scale asset purchases could have had a sizable cumulative effect on economic growth.

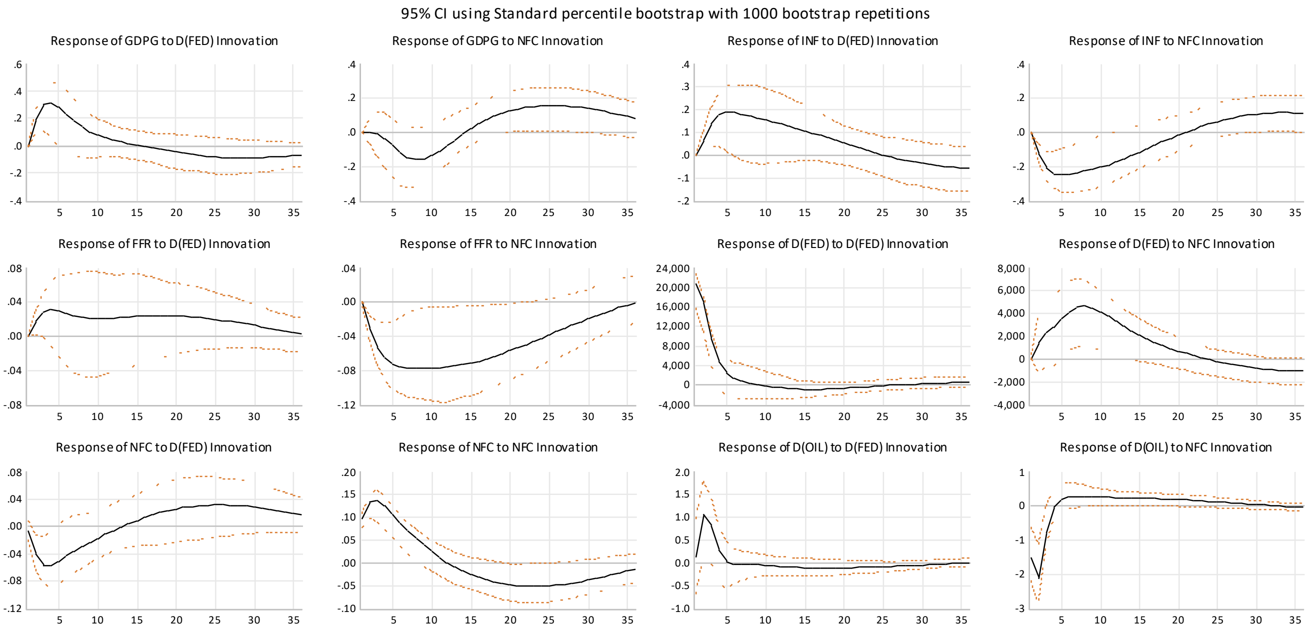
The positive effect on inflation (column 3) is fairly substantial, amounting to 0.19 percent four months after the QE shock. Inflation adjusts slowly – approximately 25 months – to equilibrium following the said shock. Although the error bands are wider compared with the growth effect, the outcome suggests that QE had the expected effect in stimulating inflation.

QE also had the expected effect reducing financial frictions, the largest effect of which occurs in period three. However, the favorable result is short-lived as financial conditions tighten slightly after the thirteenth forecast month.

The effect of QE on the systematic component of interest rate is consistent with the stimulation of inflation, namely inflation expectation (column 1, row 2). As inflation expectation increases the systematic component of the funds rate (undetermined by policy) should rise as the result indicates. However, the chart indicates that the effect is quite small relative to the inflation response and the error bands are quite wide. Therefore, QE did not only stimulate inflation expectation, but also actual inflation.

As expected, QE has a positive effect on the price of oil. The change in the oil price reaches $1.05 two months after the QE shock. The effect converges back to zero at the fifth month and remains there for the rest of the forecast horizon.

Figure 4 IRFs of QE and financial shocks



The financial shock engenders the expected response and adjustment in the endogenous variables. First, the financial shock (*nfc*) contracts real GDP growth for up to 14 months, after which point growth overshoots to positive. The lowest point of the contraction is –0.17 percent around the tenth forecast month. Inflation falls precipitously given the said shock, reaching its lowest deflationary point of –0.25 percent in the fifth month. The deflationary effect continues until month 22.

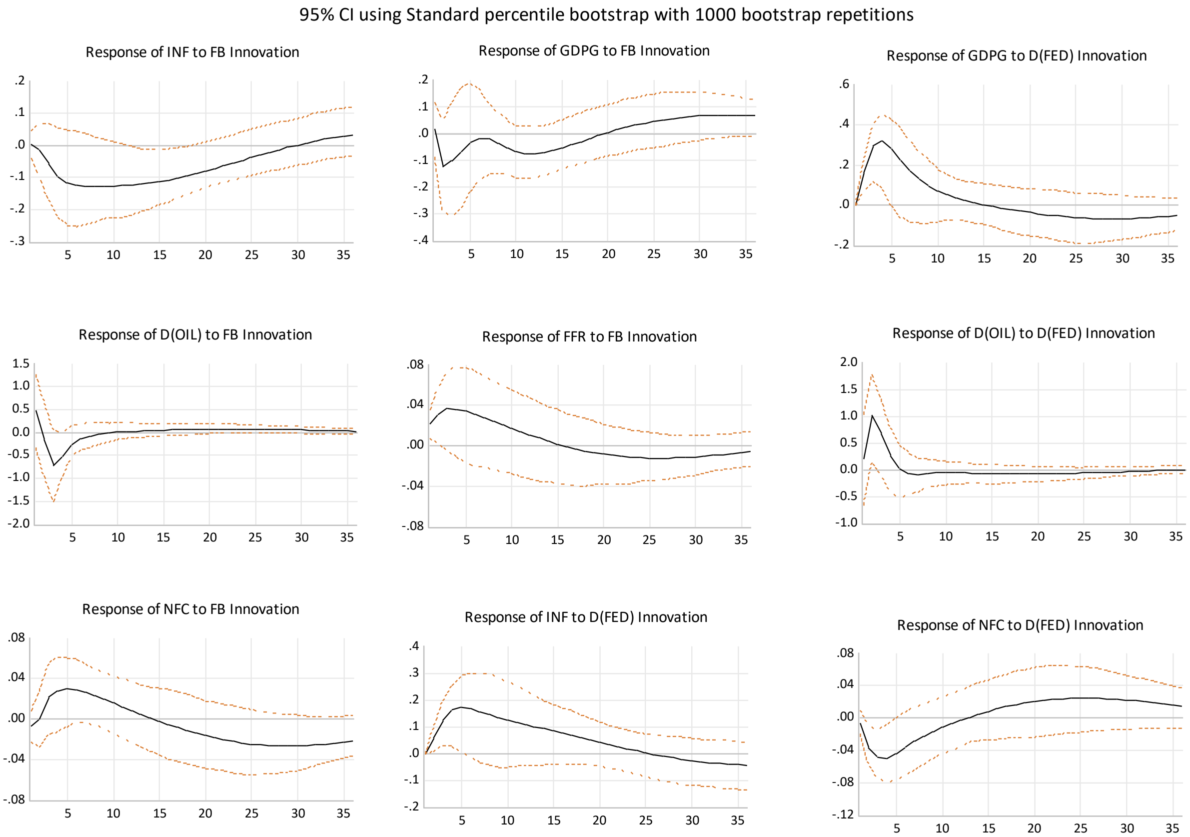
In addition, the financial shock produces a strong positive response in large asset purchases and a steep decline in the federal funds rate – thus being consistent with the intentions of the policy tools of the era (row 2, column 2 and row 2, column 4). The last chart in Figure 4 shows that oil price fell precipitously after the financial shock. The change in the price reaches –$2.10 in period two. However, the negative effect is short-lived converging to zero in period four.

Fiscal-QE model

Similar to the previous model, the SIC indicates that two lags are optimal. The model is estimated over the same time period in order to capture the QE and fiscal interventions in response to the COVID-19 pandemic and the Great Recession. It should be noted that the model was also estimated with the fiscal balance being contemporaneously endogenous to monetary policy. The results are virtually identical to the ones discussed herein. In order to present uncluttered IRFs, we will not reproduce the IRFs showing the adverse financial shock since they are very similar to those given in Figure 4. Instead, Figure 5 shows the results for the fiscal and QE shocks.

The fiscal shock produces several expected results. Similar to the previous results of Figure 3, the fiscal contraction (positive shock) reduces the inflation rate. One qualification is the disinflationary effect persists over a much longer time, approximately 30 months after the fiscal shock during the relatively more contemporary sample of 2008: March to 2022: July. Moreover, the fiscal contraction produces a longer lasting negative growth effect (row 1, column 2) compared with the longer sample: a negative effect on growth until the twentieth forecast month. The lowest growth contraction occurs in month two and amounts to –0.12 percent.

Figure 5 IRFs for the fiscal-QE model



Similar to the previous result, the fiscal contraction has a short-lived positive effect on the price of oil. Earlier, we explained that this outturn reflects the idea that oil is part of a wider portfolio of investable assets. In the crisis and post-crisis periods, a fiscal tightening has a small negative impact effect on financial friction. However, unlike the previous result, financial conditions are constrained from month two to month 15.

Interestingly, unlike the result for the longer sample, the fiscal tightening increases the systematic aspect of the federal funds rate (row 2, column 2). This result is clearly counter intuitive. Fiscal contraction will reduce the supply of tradable treasury bills and bonds, thus decreasing the interest rate of these securities as well as the systematic aspect of the funds rate (not controlled by policy shock). This result, nevertheless, appears to be statistically insignificant given the wide error bands.

The QE shock produces very similar results as given by Figure 4. In the fiscal-QE model, purchases of large amounts of financial assets are successful in motivating some inflation and also stimulating real GDP growth. It has a strong impact effect on the price of oil, as well as the dynamic adjustment until period five. Finally, QE eases financial conditions similar to previous discussions.

Historical decomposition

Using the fiscal-QE model, we investigate the contributors to inflation for the period 2020: January to 2022: July, a time known for several severe adverse shocks such as the Covid-19 pandemic, supply chain disruptions, drought in the US Midwest and the Russia-Ukraine war, as well as various policy responses such as fiscal stimuli, quantitative easing, quantitative tapering and conventional monetary tightening. The method of historical decomposition is useful for assessing which factors are the primary determinants of inflation during the specific time period. The results are illustrated by Figure 6, which shows a decomposition of the stochastic component of inflation. The leading contributing factors to high inflation in recent quarters are supply, demand, fiscal and QE shocks.

Firstly, we discuss the various fiscal stimuli that were implemented in March 2020, December 2020 and March 2021. Initially, the fiscal shocks did not track inflation well for much 2020, but eventually accounted for a substantial share in explaining the stochastic component of inflation. Although the fiscal share of inflation has started to decline after accounting for approximately 2.1 percentage points in November 2021, it has proven to be persistent from March 2021 to the end of the review period. In March 2021 the fiscal shock accounted for about 1.4 percentage points of inflation and 1.1 percentage points by July 2022.

Secondly, the demand shock has also proven to be persistent after march 2021. Furthermore, the decrease in the stochastic component of inflation is better explained by the negative demand shock of 2020. At its peak in March and April 2021, the demand shock accounted for about 1.7 percentage points. Subsequently, the inflationary effect of the demand shock has declined reaching approximately one percentage point in July 2022.

Thirdly, the adverse supply-side shocks have affected inflation with a long lag. The supply shocks do not correlate well with inflation in 2020. However, the adverse shocks continue to have an expanding effect from the last quarter of 2021 to the end of sample. At its peak in June 2022, the supply shocks accounted for about 3.05 percentage points of stochastic inflation. From February 2022, supply shocks consistently measured over two percentage points of inflation, thereby also demonstrating a degree of persistence.

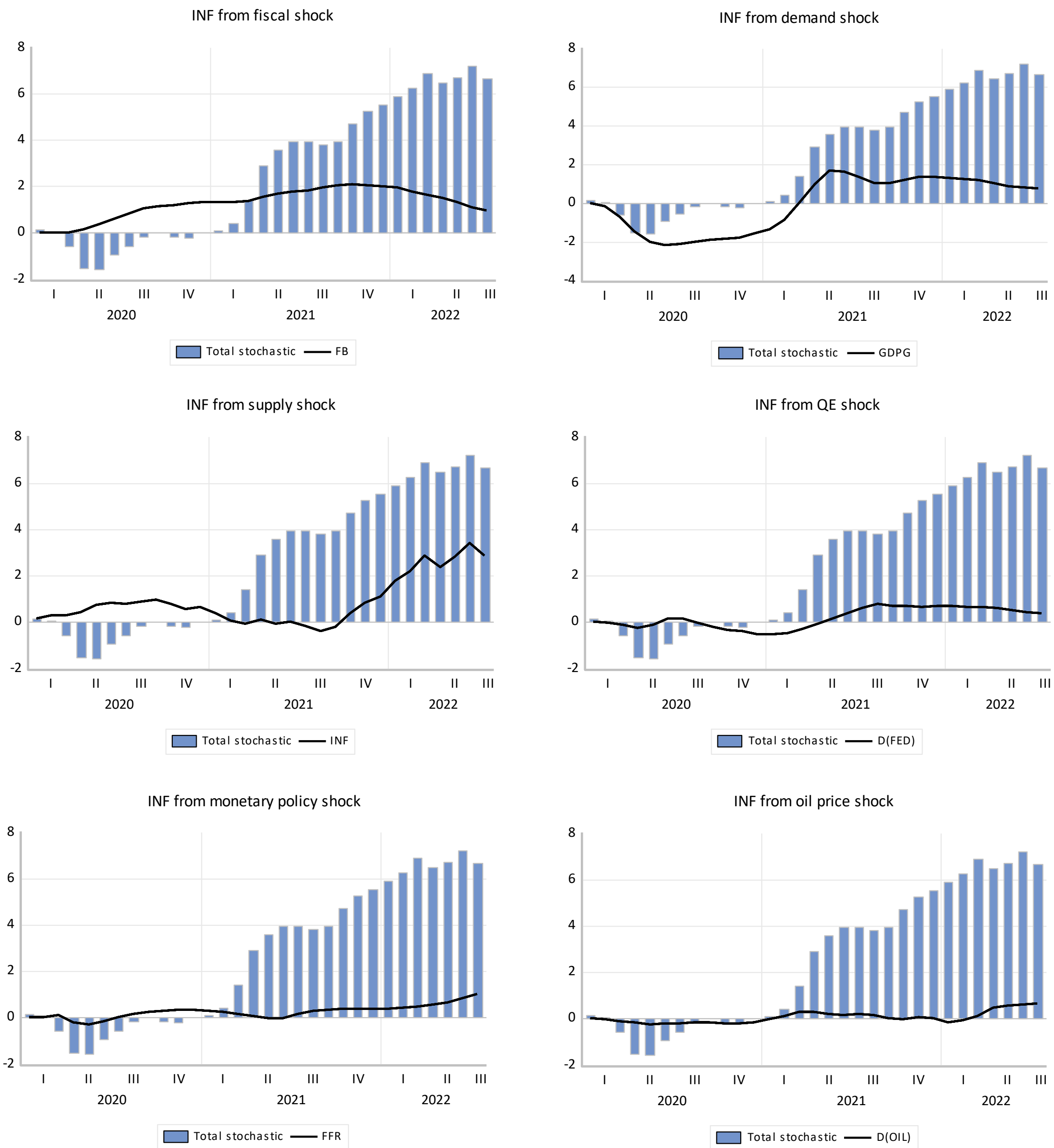
Fourthly, there was a significant expansion of the Fed's balance sheet from March 2020 to April 2022. The Fed was slowly reversing QE since early 2018 up to February 2020. Overall, QE has had a non-negligible effect on inflation commencing from around May 2021 when that effect was just 0.1 percentage points. However, the QE effect increased to a peak of around 0.95 percentage point by August 2021. The inflationary effect has been persistent, reaching 0.4 percentage point in July 2022.

Fifthly, the oil price shock appears to have a relatively small but reliable effect on inflation. The relatively low oil price for much of 2020 is associated with a fall in inflation. The lower actual oil price signals a favorable oil shock that is associated with the relatively low inflation in 2020. However, as the actual price of oil rose precipitously in March 2022, the oil shock accounts for a noticeable share of stochastic inflation from April to July 2022, amounting to a monthly average of around 0.7 percentage point of inflation.

Finally, as discussed earlier in the paper, the tightening of conventional monetary policy is often associated with higher inflation, likely caused by the feedback from higher inflation expectation. Nevertheless, survey data are reporting falling inflation expectation from April 2022. Meanwhile, the rising benchmark interest rate is accounting for an increasing effect on stochastic inflation starting from

April 2022, as reported in Figure 6. By July 2022, the monetary tightening is associated with 0.85 percentage points effect on inflation.

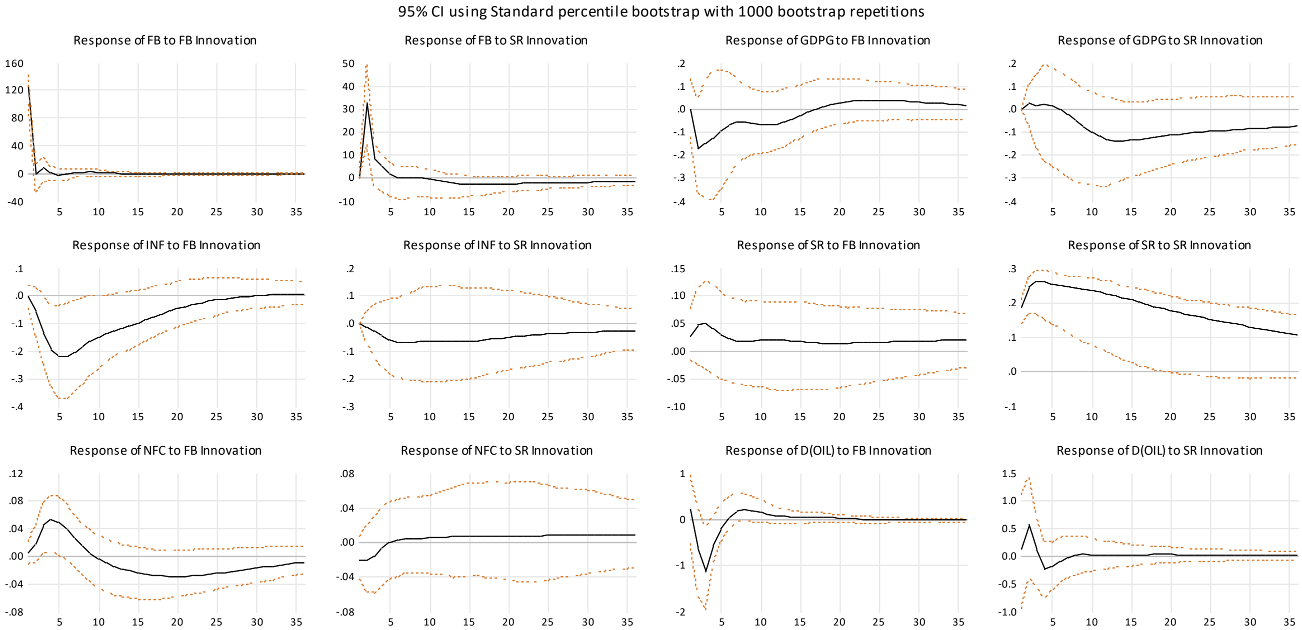
Figure 6 Historical decomposition of inflation



Fiscal-QE model with a shadow rate

Another approach to studying the effects of QE is to use a shadow rate, which is not bounded at zero (Hara et al. 2020). As another form of robustness check, we drop the Fed's balance sheet variable and replace it with the shadow rate that was created by Wu and Xia (2016). However, unlike previous studies, we also control for the fiscal balance. The recursive ordering of the variables of the variables in the SVAR is as follows: *fb*, *gdpg*, *inf*, *sr*, *nfc* and first-difference of the oil price (Δoil). The shadow-rate model is estimated with two lags as indicated by the SIC. All roots fall within the unit circle and the model is estimated from March 2008 to July 2022.

Figure 7 IRFs showing shadow-rate and fiscal shocks



Since the other shocks are largely consistent with previous results – including the *nfc* shock – we report the results for the shadow-rate shock and fiscal balance. These are given by Figure 7. The results are largely intuitive and support our previous findings. First, the fiscal balance tends to improve following a monetary shock measured by the shadow rate (row 1, column 2). This supports our previous contention as a form of implicit coordination between the Treasury and the operations desk of the Fed. Second, the QE shock measured by the shadow rate produces an unexpected result relating to economic growth, albeit statistically insignificant (row 1, column 4). Third, a monetary tightening reduces inflation, but the error bands are much wider compared with the results we obtained using the Fed balance sheet variable.

Unlike our previous results, the monetary tightening produces unintuitive and statistically insignificant adjustment in financial conditions (row 3, column 2). The shadow rate appears to have a smaller effect on oil price compared with our balance sheet variable. Overall, we conclude that the Fed balance sheet variable and the effective funds rate better control for unconventional and conventional monetary policy.

5. Conclusion

We have studied the inflationary and real growth effects of conventional and unconventional monetary policy, while also controlling for the federal government's deficits and surpluses (fiscal balance). Moreover, isolating the inflationary responses and adjustments to conventional and unconventional monetary policy require that we account carefully for supply and oil shocks as well as aggregate demand, financial friction, and fiscal shocks. By doing so, we clearly have a structural economic interpretation of our results showing the dynamics of inflation and real economic growth. Our study sheds some light on the current debate of plausible inflation-reducing strategies by analyzing the relative contribution of economic shocks on inflation. Moreover, the historical decomposition sheds light on the inflationary factors during the period of 2020: January to 2022: July.

Our findings are that Large-Scale Asset Purchases in response to the Great Recession and COVID-19 pandemic had a favorable effect on economic growth. The same policy intervention also stimulated inflation, although the magnitude was smaller and error band wider compared with the growth effect of QE. However, QE has had a non-negligible effect on inflation during 2021 and 2022. Overall, however, we conclude that the disinflationary gains from unwinding QE is much smaller than the decrease in economic growth that could result from contracting the Fed's balance sheet.

Inflation is mostly explained by a combination of adverse supply shocks, simulative demand, fiscal expansion and oil price shocks. The results indicate that inflation displays slow adjustment – a high degree of stickiness – following an oil, aggregate demand or supply shock. This has implication for the current debates surrounding whether inflation is transitory. Clearly, our estimates indicate that inflation converges after a shock (transitory), but the adjustment time to the old equilibrium (sub-2 percent) or new equilibrium (above 2 percent) exceeds three years. Given the multiple adverse disruptions and policy interventions (supply chain shock owing to the COVID-19 pandemic, fiscal stimuli, the war in the Ukraine, drought and precipitous rise in oil price) taking place since January 2020, inflation is likely to converge to 2 percent for at least five years after 2020.

Fluctuations in economic growth in the short term are explained by aggregate demand and supply shocks, as well as oil and financial-friction shocks. Following a shock, economic growth converges faster to equilibrium relative to inflation adjustment. In general, supply factors (including an oil shock) produce slower convergence in growth compared with the demand shock. Growth takes the longest to return to equilibrium after a financial shock – hence, substantiating the destructive effect of adverse financial shocks.

Financial conditions – and by extension the financial sector – play a crucial role in transmitting conventional and unconventional monetary policy impulses. For example, an increase in the federal funds rate makes financial conditions tighter. In turn, the heightened financial friction contracts economic growth and dampens inflation. As expected, a financial-friction shock has a large negative effect on oil price.

A shock to the fiscal balance (contractionary fiscal policy) decreases short-term GDP growth and inflation. Conversely, we could expect expansionary fiscal policy to stimulate short-term growth and also engender inflation over some horizon. The fiscal contraction also tends to ease financial friction. This finding calls for more discussion on the potential effect of the recent passing of the $280 billion Chips and Science Act of 2022 on inflation.

We performed several robustness tests. We estimated a baseline model for a longer timeframe without fiscal shocks, then a baseline model with fiscal shocks. The results are very similar. Even the estimates from the smaller timeframe sample produce similar results, albeit there are a few minor differences. We dropped the Fed balance sheet variable that measures QE and replaced it with the shadow rate. Overall, our approach of including two policy variables (the funds rate and Fed assets) that target two objectives (inflation and growth) provides plausible results to broaden the scope of research on inflation dynamics.

Appendix 1

Data sources

Effective federal funds rate: https://fred.stlouisfed.org/series/DFF

Shadow interest rate: https://www.atlantafed.org/cqer/research/wu-xia-shadow-federal-funds-rate

Fiscal surplus-deficit: https://fred.stlouisfed.org/series/MTSDS133FMS

Real GDP: https://fred.stlouisfed.org/series/GDPC1

Consumer price index: https://fred.stlouisfed.org/series/CPIAUCSL

GDP implicit price deflator: https://fred.stlouisfed.org/series/USAGDPDEFQISMEI

Non-financial corporate net worth: https://fred.stlouisfed.org/series/TNWMVBSNNCB

Household and non-profit net worth: https://fred.stlouisfed.org/series/TNWBSHNO

Federal debt held by Federal Reserve: https://fred.stlouisfed.org/series/FDHBFRBN

Mortgage-backed securities held by Fed: https://fred.stlouisfed.org/series/WSHOMCB

Federal agency debt securities held by Fed: https://fred.stlouisfed.org/series/FEDDT

National financial conditions index: https://fred.stlouisfed.org/series/NFCI

Interest income: https://fred.stlouisfed.org/series/PII

Rental income: https://fred.stlouisfed.org/series/A048RC1

Proprietors’ income: https://fred.stlouisfed.org/series/A041RC1

Corporate profit: https://fred.stlouisfed.org/series/A053RC1Q027SBEA

Spot crude oil price (WTI): https://fred.stlouisfed.org/series/WTISPLC

Appendix 2

Figure 1A IRFs of baseline model with twelve lags

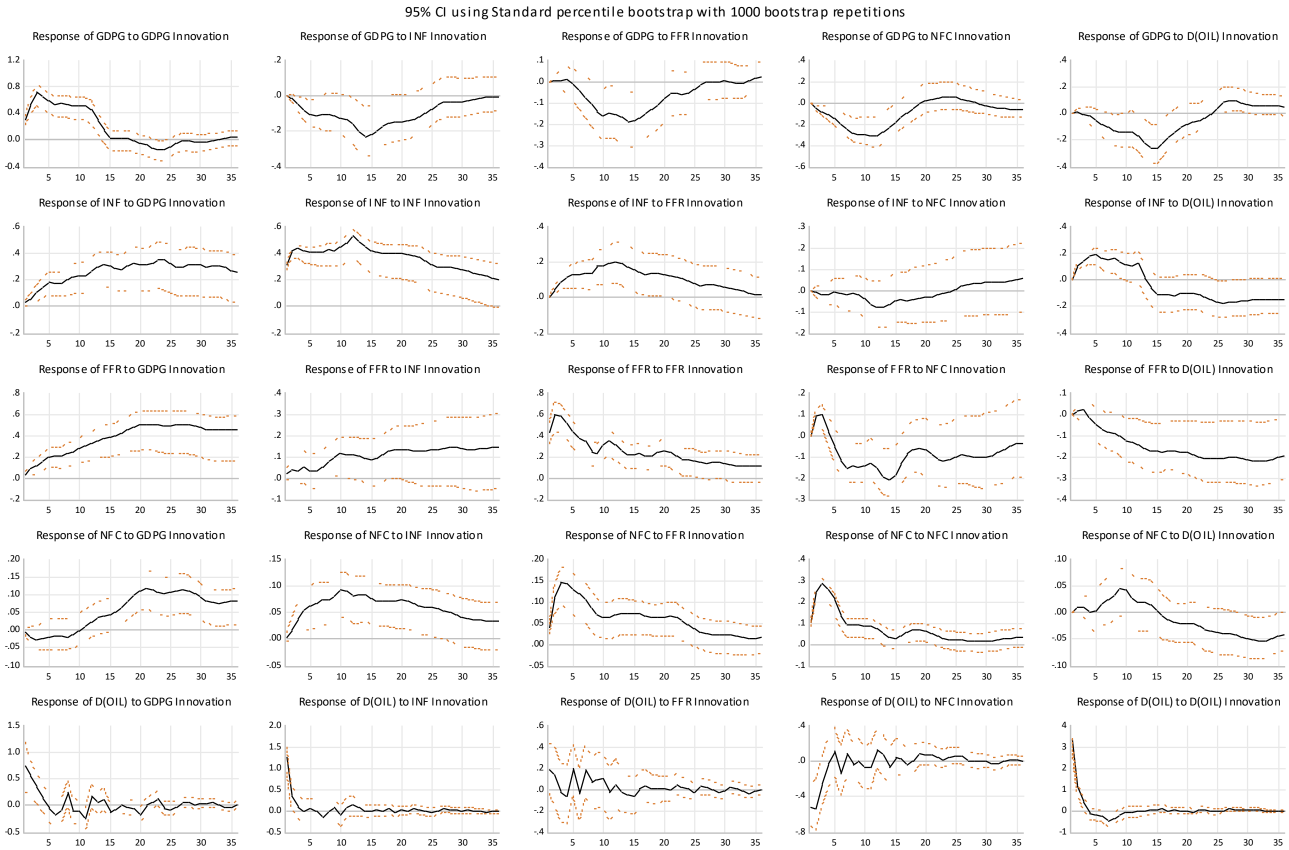
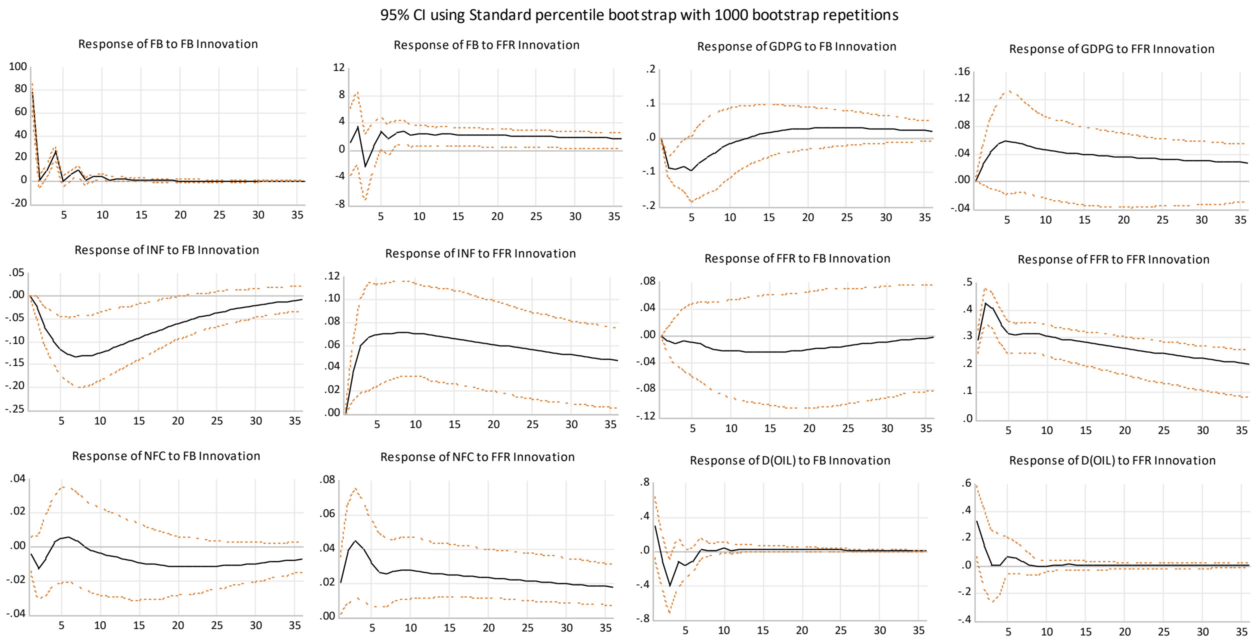


Figure 2A IRFs for fiscal-baseline model with fiscal balance endogenous to monetary policy



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