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Combining Zero and Sign Restrictions in VAR Models: Identifying Monetary Policy Shocks in Iran

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Abstract

This study examines the impacts of demand, supply, exchange rate, and unconventional monetary policy (UMP) shocks on GDP, inflation, exchange rate, and interest rate in Iran. Using sign-restriction, short-run zero-restriction, and long-run zero-restriction inside vector autoregressive frameworks, we constructed three- and four-variable models incorporating real interest rate, real exchange rate, GDP, and inflation data spanning from 1961-Q1 to 2021-Q1. We executed a bootstrap resampling technique that satisfies the signs on loops. Our findings indicate that an unconventional monetary policy, particularly a negative monetary policy shock, results in an increase in GDP and a reduction in the real exchange rate, so significantly reducing inflation. An unconventional monetary policy may be implemented to stimulate the economy. Consequently, the novel combined approach facilitates the identification of unconventional monetary policy shocks and can be broadly applied to other economic shocks. The primary question of the study is whether UMP shocks in Iran can be estimated and identified through zero and sign restrictions. Thus, the study aims to identify UMP shocks by regressing a collection of variables pertinent to the decisions of the Central Bank of Iran (CBI). Introducing UMP in emerging market and developing economies (EMDEs) such as Iran aims to attain their output and inflation targets.

Highlights

- This study seeks to establish a novel methodology for identifying unconventional monetary policy shocks with zero and negative values in the Iranian economy.
- Macroeconomic variables are used to identify shocks.
- Policymakers can significantly influence the execution of unconventional monetary policies to alleviate the detrimental impacts of economic crises within the banking sector.

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1. Introduction

The financial crisis of 2007-2009 caused monetary disruptions, leading to significant declines in real activity, which prompted central banks to lower short-term interest rates to near zero in order to stabilize their financial and real sectors. In this case, central banks would employ various unconventional monetary policy (UMP) tools, including quantitative easing (QE) and forward guidance (FG), to lower medium- and long-term interest rates and stimulate their economies. UMP has been routinely employed by numerous central banks, including the Federal Reserve (Fed), Bank of England (BOE), European Central Bank (ECB), Bank of Japan (BOJ), Swiss National Bank (SNB), Swedish Central Bank (Riksbank), and Danish National Bank (DNB). Such measures standardize lending conditions by diminishing spreads through cross-market spillovers that influence financial markets and the whole economy (Bhattarai & Neely, 2022). Consequently, the advanced economies that implemented unconventional monetary policy (UMP) from 2005 to 2020 include Denmark, the euro area, Japan, Sweden, Switzerland, the United Kingdom, and the United States, while Australia, Canada, New Zealand, and Norway did not adopt this strategy. Statistics indicate that private debt in the UMP countries has decreased. Conversely, private debt has risen in non-UMP nations, particularly in Australia and Canada, mirroring the escalation in residential property prices. It should also be emphasized that emerging countries and markets have generally opted to use unconventional monetary policy to a lesser extent than advanced economies (Turner, 2019).

Researchers have produced a more concise yet swiftly growing body of literature on the macroeconomic implications of unconventional monetary policy (UMP) utilizing dynamic stochastic general equilibrium (DSGE) models and structural vector autoregressions (SVARs). Consequently, from the onset of the 20th century, economists started to acknowledge the importance of impulses and transmission processes in elucidating business cycle swings. A substantial corpus of research spanning the 1940s to the 1970s concentrated on fiscal and monetary policy shocks identified from extensive econometric models or single-equation analyses (Ramey, 2016; Cochrane, 1994). In the 1980s, Sims (1980) proposed vector autoregressions (VARs), establishing a connection among innovations in a linear system, hence facilitating discussions of macroeconomic shocks through the identification of hypotheses for estimating impulse response functions and forecast error decompositions. Sims (1980) equated innovations with macroeconomic shocks. Kydland & Prescott (1982) expanded their study beyond policy shocks to include significant non-policy shocks, particularly technology shocks. Ultimately, these innovations have sparked a surge of research on shocks.

The primary question of the study is whether UMP shocks in Iran can be estimated and identified through zero and sign restrictions. The study aims to identify UMP shocks by regressing a collection of variables pertinent to the decisions of the Central Bank of Iran (CBI). The study considers shocks that are most closely associated with structural disturbances and exogenous forces that are uncorrelated, as utilized by researchers including Blanchard & Watson (1986), Bernanke (1986), and Stock & Watson (2002, 2012). Consequently, due to the low importance of unconventional monetary policy in Iran, this study examines the shocks, particularly the UMP shock, using vector autoregression (VAR) and estimates them with zero and sign restrictions. The unprecedented economic impact of the crisis necessitate extensive fiscal and monetary support to safeguard the welfare of individuals and enterprises in Iran, and we propose that UMP be implemented to enhance economic conditions. Introducing UMP in emerging market and developing economies (EMDEs) such as Iran aims to achieve two objectives: (1) expanding monetary policy capacity to assist central banks in attaining their output and inflation targets, and (2) alleviating constraints on monetary transmission in the allocation of credit to areas of greatest need. Central banks in emerging markets and developing economies should evaluate the composition of intermediate balance sheets, including micro and macroprudential measures and the banking sector's profitability, when implementing UMP (Hofman & Kamber,2020).

The subsequent sections of this study are structured as follows: Section Two commences with a summary of various studies examining the impacts of monetary policy. Section Three addresses conventional monetary policy, unconventional monetary policy, and the many channels of monetary transmission employed in the implementation of monetary policy. Sections Four and Five examine research methodologies, particularly various identification schemes related to shocks in interest rates, inflation, real exchange rates, GDP, and empirical findings. Section Six ultimately delineates the conclusions of this study.

2. A Review of the Related Literature

Multiple researches have examined the impacts of unconventional monetary policies (UMP). For this research, several studies pertinent to the subject were examined. In recent years, Ma (2024) examined the dynamic responses of essential U.S. macroeconomic variables to the Federal Reserve's unconventional monetary policy using a newly established instrumental variable structural VAR framework throughout the period from 2010 to 2019. Dwyer et al. (2023) examined the efficacy of asset purchase programs in initiating unconventional monetary policy to comprehend the impacts of monetary policy shocks. They propose that such policies may serve as vital instruments for economies undergoing financial market distress. Numerous studies on monetary policy shocks assert that unconventional monetary policy shocks yield expansionary impacts, including heightened output and private investment (Bi and Traume, 2023; Hohberger et al., 2023). Lyu et al. (2023) examined the dynamic impacts of unconventional monetary policies on economic stabilization by assessing the efficacy of the ECB's unconventional monetary measures since the beginning of the financial crisis. Girotti et al. (2022) conducted a study on the implementation effects of NIRP and discovered that it reduces loan rates for enterprises via a portfolio rebalancing mechanism. According to empirical research by Altavilla et al. (2022), utilizing confidential data from the Euro area, healthy banks transmit negative rates to their corporate depositors without encountering a reduction in funding. This enables them to extend greater credit than other banks. The actual impact of the NIRP on corporate investment is chiefly linked to enterprises adjusting their asset allocations. Furthermore, Gudarzi Farahani & Adeli (2022) corroborated the association between monetary policy and the exchange rate in their research. The exchange rate reacts to monetary policy shocks identified by Gurkaynak et al. (2021), who analyzed quarterly data from the Euro Area and US real GDP, short-term interest rates, and CPI from 1998 to 2008. Additionally, Churm et al. (2021) examined the impact of monetary policy on macroeconomic indicators. They found that monetary shocks enhance production. Consistent with the aforementioned studies, Mateju (2019) examined the impact of monetary policy interest rate shocks using Bayesian TVP-VAR models. The author employed a quarterly dataset comprising seasonally adjusted log-GDP, log-CPI, money market interest rate, logarithm of the nominal effective exchange rate, and logarithm of the oil price index as exogenous variables. The findings demonstrate time-varying impulse responses of the price level and GDP to a monetary policy shock, utilizing a combination of short-term and sign restrictions. Quantitative easing is regarded as an unconventional monetary policy tool that positively influences GDP, investment, and non-oil exports in Iran (Mohseni et al., 2019). Unconventional monetary policy can more significantly impact GDP and investment in Iran (Mohseni et al., 2019). Research, such as that conducted by Arias et al. (2018), demonstrates that monetary policy shocks result in a reduction in GDP, due to contractionary monetary policy shocks utilizing a sign restriction approach. Angrick & Nemoto (2017) examined negative policy rates, wherein major economies reduced rates to combat deflationary trends and economic fragility. To underscore the balance sheet channel in the monetary transmission mechanism in Iran, Mohseni Zenori (2017) primarily concentrated on the response of GDP to monetary, price, and exchange rate shocks, demonstrated that reducing the interest rate tends to stimulate investment, hence decreasing production costs, enhancing national output, and generating a surplus supply in society, which is partially effective in regulating prices. Furthermore, Shihaki Tash (2015) posited that the relationship between interest rates and unemployment suggests that unconventional monetary policy may significantly incentivize investment, hence fostering new job prospects, ultimately enhancing the employment rate and diminishing unemployment in Iran. Baumeister & Benati (2010) utilized a quarterly dataset comprising real GDP, the GDP deflator, and a short-term interest rate from the European Central Bank’s database for the period 1970:1–2008:4. The authors determined that UMP measures had mitigated substantial risks of output decline. Canova & Pina (2005), Uhlig (2005), Canova & De Nicolo (2002), Dwyer (1998), and Faust (1998) suggested imposing sign restrictions on the impulse responses of variables to identify monetary policy

shocks in their respective studies.
The subsequent table summarizes other studies along with their findings.

Table 1. summary of Pertinent studies

paper	Methodology	Data	variables	Mainresults
Carvalho etal. (2024)	Structural vector error correction model	1971-2019	exchange rates interest rate inflation output	Monetary policy influences exchange rates and inflation.
Fratto et al. (2021)	an event study methodology	2020	bond yields, exchange rates, equities, and debt spreads	UMP may serve as significant instruments for EMDEs amid financial market stress.
Vaille(2021)	BVAR and Panel VAR	2008-2018	Interest rate Total asset systematic risk	UMP shocks lead to a reduction in systemic risk. The interplay between real GDP and consumer prices indicates that unconventional monetary policy shocks implemented post-financial crisis effectively bolstered the macroeconomy.
Kapinos (2021)	TFP-VAR	1987-2010	Interest rate Output gap, unemployment rate, real output growth rate, GDP/GNP deflator and inflation.	Monetary news shocks indicating forthcoming interest rate decreases effectively reduce prices.
De Santis & Holm-Hadulla, (2020)	two-stage least squares (2SLS) instrumental variable estimation	daily observations from March 9, 2015 to June 21, 2016	euro area sovereign bond yields and purchase operations data	The Public Sector Purchase Program is useful in unconventional monetary policy.

Hartley and Rebucci(2020)	an event study methodology	2020	10-year bond yield and asset purchase program announcements	The QE announcement, as a tool of UMP, has a statistically significant effect during the Great Recession period.
Cheng & Yang (2020)	(SVAR) model witha combination of narrative sign restrictions and sign restrictions	monthly data from 1965:1to2007:6.	GDP, the GDP deflator, the commodity price index, total reserves, non-borrowed reserves, and the federal funds rate.	Monetary policy influences GDP.
Keshavarz and Parsa (2019)	DSGE model and Bayesian method	seasonal data of 2005-2017	GDP, monetary base, consumption, government expenditures	Monetary policy influences macroeconomic factors.
Inoue & Rossi (2019)	reduced-form VAR model and high frequency identification	1995-2012	Interest rate exchange rates	Monetary policy shocks within a nation result in fluctuations in exchange rates.
Bottero et al. (2019)	OLS	2013-2015	Interest rate net investment liquidity	Negative Interest RatePolicy affects companies via a portfolio reallocation channel.
Inoue & Rossi (2018)	"VAR with Functional Shocks" approach	between January 1995 and June 2016	data on daily US bond yields	They discovered UMP shocks that resulted in an increase in output growth.
Boeckx et al. (2017)	structural VAR framework	2007:M1–2014:M12	Policy rate Prices output	The dynamic impacts of unconventional monetary policies often enhance the liquidity surplus.
Stavrakeva & Tang (2015)	VAR	1990:Q1-2015:Q1	Exchange Rates Short-term ratesGDP Deflator, Output Gap	The relationship between monetary policy and the Exchange rate was confirmed.

Castelnuovo (2012)	Tri-variateVAR with sign restriction approach	quarterly U.S. data,1984:I-2008:II	inflation,output, and interest rate	A monetary policy shock impacts output.

Source:

In addition to UMP shock, the current study includes a broader array of shocks, such as demand, exchange rate, and supply shocks, concerning Iran. This study introduces the sign restriction approach to enhance UMP conduction in Iran, utilizing an updated dataset from 1961-Q1 to 2021-Q1 to identify shocks through the algorithms developed by Arias et al. (2014) and Uhlig (2005), contrasting previous models. This study examines zero restrictions, encompassing 'short-run' zero restrictions (e.g., Sims, 1980) and 'long-run' zero restrictions (e.g., Blanchard and Quah, 1989) (Giacomini et al., 2021).

3. Theoretical Framework

3.1 Conventional monetary policy and unconventional monetary policy

The central bank's objectives largely govern monetary policy, focusing on maintaining inflation near a target level in the medium term while simultaneously pursuing employment goals. During the pre-crisis period, the majority of central banks implemented similar measures for monetary policy, but with variations in their operational frameworks. The primary tool of conventional monetary policy (CMP) was the regulation of a short-term interest rate, whereby alterations in this policy rate and the public's anticipations regarding its future adjustments influenced financial conditions and the macroeconomy, including the accessibility and cost of funding, aggregate expenditure, output, and inflation. The transmission mechanism of conventional monetary policy from the policy rate to financial conditions encompasses connections with short-term funding markets, loan markets, exchange rates, and equity markets (refer to Figure 1) (Potter and Smets, 2019).

Figure 1. Depiction of the monetary transmission mechanism.
Source: Potter & Smets(2019)

The global financial crisis drastically interrupted this setup, compelling numerous central banks to abandon the conventional framework. Amid the crisis, due to its detrimental impact on the global economy and the demand for elevated risk premiums by financial market participants, numerous central banks encountered an impaired financial sector, reaching the constraints of their conventional tools. Financial conditions inadequately reacted to decreases in policy rates, and conventional policy easing encountered limitations due to the effective lower bound. Consequently, central banks progressively implemented a series of policy instruments known as unconventional monetary policy(UMP) tools. Numerous studies offer empirical evidence about the ineffectiveness of conventional monetary policy during financial crises (Hubrich & Tetlow, 2015; Potter & Smets, 2019).

The utilization of UMP tools progressed in phases, primarily aimed at two objectives: (i) addressing disturbances in the monetary policy transmission mechanism; and (ii) providing supplementary monetary stimulus when the policy rate was limited by the effective lower bound (ELB). Certain measures of UMP were intended to impact long-term risk-free rates, whereas others aimed to influence liquidity and interest rates on other non-risk-free securities. Due to achieving policy rates at an ELB, central banks could no longer provide monetary stimulus through conventional methods, necessitating the employment of other instruments. Alternative tools are categorized into four types, which are elaborated upon below:

1)Negative policy rates policies (NIRP) were unconventional in the sense implying that the owner of excess reserves incurs a cost for saving them in the central bank, overturning the usual pattern of interest payment flows in a monetary economy (Potter & Smets, 2019). 2) in Expanded lending operations (LOs), as known as an expanded lending operations to financial intermediaries, central banks created an extended lending facilities to provide ample liquidity to a wider array of financial institutions at the same time, under considerably looser conditions by allowing lower-quality collateral, for longer horizons, and possibly at a lower cost (Potter & Smets, 2019). 3) Asset purchase programs (APPs) consisted of central bank's large-scale purchases of assets, typically funded by the creation of central bank reserves, may lead to increased liquidity and to exchange rate depreciation. APPs affect the economy indirectly when bank's liquidity constraints reduced and as a result, they increase credit supply. Such a tool is suitable for EMDEs where exchange rate fluctuations are a primary source of volatility and vulnerability (Fratto, 2021). 4) Forward guidance is known as signaling central bank's willingness to pursue extraordinary policy actions for an extended period. The tool can remove uncertainty about the future of interest rate and compress risk premia (Cole & Huh, 2024; Borio & Zhu, 2012). The main message of all tools is that many of them were, in some respects, not fundamentally different from tools central banks had used in the past. Furthermore, the deployment of multiple tools can mitigate the side effects of each tool could have produced in isolation. In coordination of UMP with other policies, it should be noted that UMP tools were not the only tools deployed by policymakers during the financial crisis to deal with economic downturn. A number of structural, fiscal, micro prudential and macroprudential policies were also introduced. While all these measures were broadly directed to overlapping objectives (Potter & Smets, 2019). Also, Keynes (1936) offered a "unorthodox" policies or UMP to monetary authorities to reduce interest rates and reverse the crisis.

3.2 The channels of monetary transmission

Assessing the impact of monetary policy on the economy necessitates identifying an effective transmission mechanism by which monetary policy actions influence aggregate demand and, eventually, inflation. The conventional channels of monetary transmission are succinctly explained below:

1)The interest rate channel, being the primary mechanism of monetary policy transmission, signifies that alterations in the monetary policy stance lead to variations in the overall interest rates within the economy. This then influences the demand for credit and the disposable income of both borrowers and lenders. Fluctuations in interest rates modify the marginal cost of borrowing, resulting in alterations in investment and savings, and significant shifts in aggregate demand. 2)Asset Price Channel: In this channel, alterations in monetary policy influence asset prices within the economy, thereby prompting variations in consumption and investment via the wealth effect. The degree of development and significance of the bond, equity, and real estate markets in the economy are the primary elements affecting the efficacy of this channel. 3)Exchange Rate Channel: Modifications in the monetary policy stance that result in fluctuations in the exchange rate subsequently affect the competitiveness of both domestic and foreign goods and services. This consequently influences the relative demand for both domestic and foreign goods and services. 4) Availability of credit channels: Modifications in monetary policy frequently lead to alterations in the accessibility of credit. This illustrates how asymmetric information and the cost of contract enforcement can engender agency difficulties in marketplaces. 5)The bank lending channel: Through this route, monetary policy can be contingent upon the lending capability of banks to enterprises. 6)The balance sheet channel: This channel typically illustrates how monetary policy influences firm's borrowing capability from markets, contingent upon alterations in their net worth resulting from monetary policy decisions (Mishkin,1996).

In this section, we first implemented the interest rate channel. Subsequently, regarding the consequences of monetary policy shocks, we examined a New Keynesian economy with equilibrium conditions in the subsequent three models (Gali, 1961; Walsh, 2010). The fourth model incorporated the exchange rate channel:

$$\mathrm{y}_t = E_t(\mathrm{y}_{t+1}) - \frac{1}{\sigma}(\mathrm{r}_t - \mathrm{E}_t(\pi_{t+1}) - \mathrm{r}^*) + w_t^d \qquad (IS) \qquad (1)$$

$$\pi_t = E_t(\pi_{t+1}) - k\mathrm{y}_t + w_t^s \qquad (NKPC) \qquad (2)$$

$$\mathrm{r}_t = (1-\varphi_r)\left[\mathrm{r}^* + \varphi_\pi \pi_t + \varphi_y y_t\right] + \varphi_r r_{t-1} + w_t^m \qquad (MP) \qquad (3)$$

In which,

$$w_t^d = \rho_d w_{t-1}^d + \sigma_d w_t^d \qquad (4)$$

$$w_t^s = \rho_s w_{t-1}^s + \sigma_s w_t^s \qquad (5)$$

$$w_t^m = \rho_m w_{t-1}^m + \sigma_m w_t^m \qquad (6)$$

$$(w_t^d, w_t^s, w_t^m) \sim N(0, I)$$

Where:

y represents GDP, r signifies the nominal interest rate, r^* indicates the real interest rate, Π symbolizes inflation, w_t^drefers to demand shock, w_t^s pertains to supply shock, and w_t^mrelates to monetary policy shock. Equation (1) denotes the demand equation, Equation (2) signifies the New Keynesian Phillips curve, and Equation (3) illustrates the monetary policy rule. Clarida et al. (2002) assert that the nominal exchange rate can be determined using the consumer price index, market clearing conditions, and purchasing power parity. Consequently, the nominal exchange rate is:

$$e_t = s_t + p_{H,t} - {p^*}_{H,t} \tag{7}$$

$$w_t^e = \rho_e w_{t-1}^e + \sigma_e w_t^e \tag{8}$$

Where s_t represents the terms of trade, w_t^e denotes the exchange rate shock, $p_{H,t}$ signifies the domestic goods price levels, and ${p^*}_{H,t}$ indicates the foreign goods price levels, with the following relationships:

$$s_t = y_t - {y^*}_t \tag{9}$$

$$p_{H,t} = p_{H,t-1} + \pi_t \tag{10}$$

$${p^*}_{H,t} = {p^*}_{H,t-1} + {\pi^*}_t \tag{11}$$

Furthermore, y_t represents the domestic output level, ${y^*}_t$denotes the foreign production level, $\pi_t$indicates domestic inflation, and ${\pi^*}_t$ signifies international inflation.

We assess the efficacy of a UMP in the economy utilizing the frameworks of Minsky (2008b) and Davidson (1972). They recognize that the current stocks accrued from prior periods are inadequate to satisfy demand, hence requiring additional production by UMP. Nevertheless, in the absence of additional assumptions or evidence, we are unable to identify the parameters or shocks. Consequently, the study seeks to identify an UMP shock affecting the Iranian economy. The study also identifies several shocks based on the liquidity effect. Ultimately, by analyzing these shocks, we want to determine the most effective shock for Iran's economy.

4. Research Methodology

Monetary policy can be described in numerous functional forms, which ultimately influence the outcomes of the final relationships. To identify the shocks referenced in the preceding section, we employ sign-restriction, short-run zero-restriction, and long-run zero-restriction within vector autoregressive models, including SVAR, to ascertain VAR. To this end, we examine the subsequent SVAR relationship:

$$B(L)X_t = c + \varepsilon_t \tag{12}$$

In the equation $B(L) = B_0 - B_1 L - \cdots - B_p, B, c,$ and ε_t represent the lag polynomial, unknown coefficients, a vector of constants, and an n×1 vector of zero-mean, serially uncorrelated structural shocks, respectively. The identity covariance matrix is $E(\varepsilon_t \acute{\varepsilon}_t) = I_n$. The correlation between coefficients and shocks within the VAR framework complicates the attainment of an accurate assessment. Consequently, by resolving this equation, the reduced-form VAR relationship is as follows:

$$A(L)X_t = \mu + u_t \quad (13)$$

Where $A(L) = I - A_1 L - \cdots - A_p L^p$, $A_j = B_0^{-1} B_j$, $\mu = B_0^{-1} c$, and $u_t = B_0^{-1} \varepsilon_t$.The objective is to extract the structural parameters of interest from the reduced-form VAR presented in Eq. (13), as indicated in Eq. (12). Due to the disparity between the calculated parameters and structural parameters, the identification problem necessitates $n(n-1)/2$ identification restrictions. Eq. (13) is encapsulated by the subsequent set of relations (Maboudian & Ehsani, 2019; Rossi, 2018):

$$X_t = A(L)^{-1}\mu + A(L)^{-1}u_t \quad (14)$$

According to $A(L)^{-1}\mu = k$, $A(L)^{-1}u_t = \varepsilon_t$ and $A(L)^{-1} = \theta$

$$X_t = k + \theta_0 u_t + \theta_1 u_{t-1} + \cdots + \theta_{q-1} u_{t-(q-1)} + \theta_q u_{t-q} + \cdots \quad (15)$$

And also $B_0^{-1} B_0 = I$, $u_t = B_0^{-1}\varepsilon_t$ with $\varepsilon_t = B_0 u_t$

$$X_t = k + \theta_0 B_0^{-1} B_0 u_t + \theta_1 B_0^{-1} B_0 u_{t-1} + \cdots + \theta_{q-1} B_0^{-1} B_0 u_{t-(q-1)} + \theta_q B_0^{-1} B_0 u_{t-q} + \cdots \quad (16)$$

$$X_t = k + \theta_0 B_0^{-1}\varepsilon_t + \theta_1 B_0^{-1}\varepsilon_{t-1} + \cdots + \theta_{q-1} B_0^{-1}\varepsilon_{t-(q-1)} + \theta_q B_0^{-1}\varepsilon_{t-q} + \cdots \quad (17)$$

The structural form is subsequently transformed into a moving average as outlined by Watson (1994):

$$X_t = k + \tilde{\theta}_0 \varepsilon_t + \tilde{\theta}_1 \varepsilon_{t-1} + \cdots + \tilde{\theta}_{q-1} \varepsilon_{t-(q-1)} + \tilde{\theta}_q \varepsilon_{t-q} + \cdots \quad (18)$$

From the reduced-form VAR model in Eq. (18), we derive the impulse response function (IRF) $(\theta_0, \theta_1, \theta_2, \dots, \theta_p)$ (Sims, 1980). An orthogonalization procedure is necessary to derive the IRF from the appropriate distribution. At this point, we analyze the substantial restrictions on structural impulse response functions. Should the restrictions be met, as delineated in the model, we maintain the outcomes. In this instance, the candidate structural shocks are generated by multiplying P by the specified matrix R, which is structured as follows:

$$R = \begin{bmatrix} \cos(\mu) & \sin(\mu) & 0 \\ \sin(\mu) & -\cos(\mu) & 0 \\ 0 & 0 & 1 \end{bmatrix} : \mu \epsilon [-\pi, \pi] \quad (19)$$

Upon deriving R, only shocks that comply with the sign restrictions inside the interval are chosen. Notably, altering μ modifies the impulse responses of all variables to shocks. Analogous to the sign restriction scenario, we employ B as structural parameters to aggregate the IRFs for the zero restriction at the specified horizon. The sign-restrictions on IRFs are encapsulated by the S_j matrix for $1 \leq j \leq n$, with the number of columns in S_j corresponding to the number of rows in f (B). Typically, S_j functions as a selection matrix, possessing precisely one non-zero element per row. If the rank of $S_j$is s_j, then s_j represents the number of sign restrictions on the IRFs to the jth structural shock. The aggregate number of sign restrictions is expressed as $S_j = \sum_{j=1}^{n} s_j$. Let $e_j$represent the jth column of I_n, where $I_n$is the $n \times n$ identity matrix. This analysis is based on two assumptions. 1) B asserts that the parameters satisfy sign restrictions (given that it is negative) if and only if $S_j f(B) e_j < 0$, for $1 \leq j \leq n$. 2) B asserts that the parameters satisfy zero restrictions if and only if $Z_j f(B) e_j = 0$, for $1 \leq j \leq n$, provided that we also intend to apply zero restrictions across several horizons, akin to the scenario of sign restrictions. We utilize the function f (B). The zero restrictions are denoted by matrices $Z_j$for $1 \leq j \leq n$. If the rank of Z_j is z_j, then the total number of zero restrictions is $z = \sum_{j=1}^{n} z_j$.

A conventional method of identification entails recursive identification (Sims, 1980). The method is inapplicable at the zero lower bound due to the interest rate being 0 or occasionally negative; hence, VAR estimation is not feasible, necessitating the usage of sign restrictions. Alongside the sign restrictions technique, various identification schemes appropriate for the zero lower bound are examined in the following: 1) The shadow rate posits a "shadow" yield curve that is linear in Gaussian factors, potentially resulting in negative values at short maturities, despite the true short-term rate being the maximum of the shadow rate or zero (Wu & Xia, 2020; Krippner, 2013). 2) Identification based on heteroskedasticity: It utilizes supplementary restrictions based on the temporal variability in variance of the shocks (Wright, 2012). 3) High-Frequency Identification: It identifies monetary policy shocks as alterations in financial market expectations within a brief temporal window around a monetary policy announcement (Kuttner, 2001). 4) External Instruments: An additional method for identifying UMP shocks from VARs is to utilize external sources of information called external instruments. External instruments are variables that are correlated with the shock of interest but not with other shocks (Montiel-Olea et al., 2012). 5) VARs with Functional Shocks: The shock represents an exogenous movement in the yield curve due to monetary policy and is also a function (Inoue & Rossi, 2018).

4.1 Data and model specification

A comprehensive set of variables is utilized for the analysis, covering the period from the first quarter of 1961 to the first quarter of 2021. The data are sourced from the World Bank and Central Bank datasets. Due to the potential for random volatility in monthly data, we present the empirical findings derived from quarterly data (Demiralp et al., 2021). The theoretical model incorporates the following variables: real interest rate (R), Gross Domestic Product (GDP), real exchange rate (ER), and inflation (INF). The real interest rate is determined by deducting the nominal interest rate from the inflation rate. Gross Domestic Product (GDP) is the aggregate of the gross value added by all domestic producers within the economy, augmented by product taxes and diminished by subsidies not incorporated in the product value. Inflation, indicated by the consumer price index, represents the quarterly percentage variation in the costs incurred by the average consumer for acquiring a basket of goods and services. Inflation can be quantified over predetermined or designated periods, such as annually. The official exchange rate is the rate established by national government or the rate set in the legally sanctioned exchange market (World Bank, 2023). Consequently, to identify the effects of UMP shocks, both models must incorporate diverse variables in accordance with the frameworks established by Stock & Watson (2001), Gurkaynak et al. (2021), Madeira et al. (2023), and Carvalho et al. (2024). Thus, the subsequent models are employed:

Model 1: $X_t = (r, inf, gdp)$ (20)

Model 2: $X_t = (r, inf, gdp, er)$ (21)

To estimate the aforementioned models, we identify structural shocks employing a combination of zero short-term, zero long-term, and sign-restrictions (Fry & Pagan, 2011). Sign-restriction identification has been commonly employed in the research of monetary policy (Canova & De Nicolo 2002; Uhlig 2005; Rafiq & Mallick 2008; Scholl & Uhlig (2008); Jarocinski (2010). This study aims to identify four types of shocks, restricting them according to specific patterns utilizing two models that elucidate the signs based on Iran's economic structure, as well as the research conducted by Stock & Watson (2001), Castelnuovo (2012), Gurkaynak et al. (2021), and Madeira et al. (2023).

Table 2. signs restricted on shocks

variable or shock	**dlog gdp**	**dlog inf**	r	**dlog er**
supply Shock	−	+	−	+
demand Shock	+	+	−	+
MP Shock	+	−	−	−
MP Shock (short run)	?	?	0	?
MP Shock (long run)	?	?	0	?
exchange rate shock	+	−	−	+

Source: *Stock & Watson (2001) and Gurkaynak et al. (2021)*

5. Empirical Results

This section encapsulates the principal estimation results. We categorize the shocks as supply shocks, demand shocks, exchange rate shocks or UMP shocks, depending on their effects on inflation, output, exchange rate and interest rates, as outlined by Madeira et al. (2023). All variables are presented in logarithmic levels, with the exception of the interest rate, which is expressed in non-logarithmic form. Upon examining the time-series aspect of the data, we perform stationarity tests and determine that all series for the sample period are stationary, with the exception of GDP (Table 3).

Table 3. results of stationary test

variables	Test statistics	Dickey-Fuller critical value		
		1%	5%	10%
r	-3.860	-2.581	-1.950	-1.619
inf	-4.912	-3.994	-3.431	-3.131
gdp	6.259	-2.581	-1.950	-1.619
er	4.865	-3.463	-2.881	-2.571

Source: *Research finding*

5.1 Impulse response functions

This section introduces a straightforward framework for identifying four shocks (i.e., UMP shocks) using three methodologies: sign-restriction (SR), short-run zero-restriction (OIR), and long-run zero-restriction (BQ) within a vector autoregressive context. The estimation is conducted with two lags, clearly demonstrating the impact of the variables. Models estimated by SR indicate that a negative shock to the interest rate results in a decline in the exchange rate, facilitating Iran's ability to import goods at reduced costs and demonstrating that the exchange rate is responsive to UMP shocks. This, in turn, leads to the appreciation of the national currency and an increase in GDP. In the initial and second models, a total of 6602 and 55084 draws are conducted to produce a SR in order of sequence. Furthermore, 100 randomly selected impulse responses that satisfy sign restrictions are generated in both models to illustrate how typical responses may manifest. Subsequently, we examine the impact of zero-restriction on the interest rate by choosing the OIR and BQ. The results are largely aligned with the liquidity effect of monetary policy shocks, wherein a significant increase in money supply occurs following a decrease in interest rates, leading to an increase in investment and GDP. Accordingly, according to Rossi (2018) proposed that sign restrictions serve as an identification method for identifying monetary policy shocks, we impose the reactions of particular variables to specific

Figure 2: IRFs to 3 shocks identified using SR and BQ approach

***Source:** Research finding*

structural shocks with designated signs. Consequently, SR, OIR as well as BQ on interest rates enables the identification of an UMP. The primary result illustrated in Figure 2 is the impact of monetary policy shock on inflation and GDP. Furthermore, the impulse response functions of four variables in response to four shocks, found using the SR and BQ are provided, demonstrating that the results of both methods are identical.

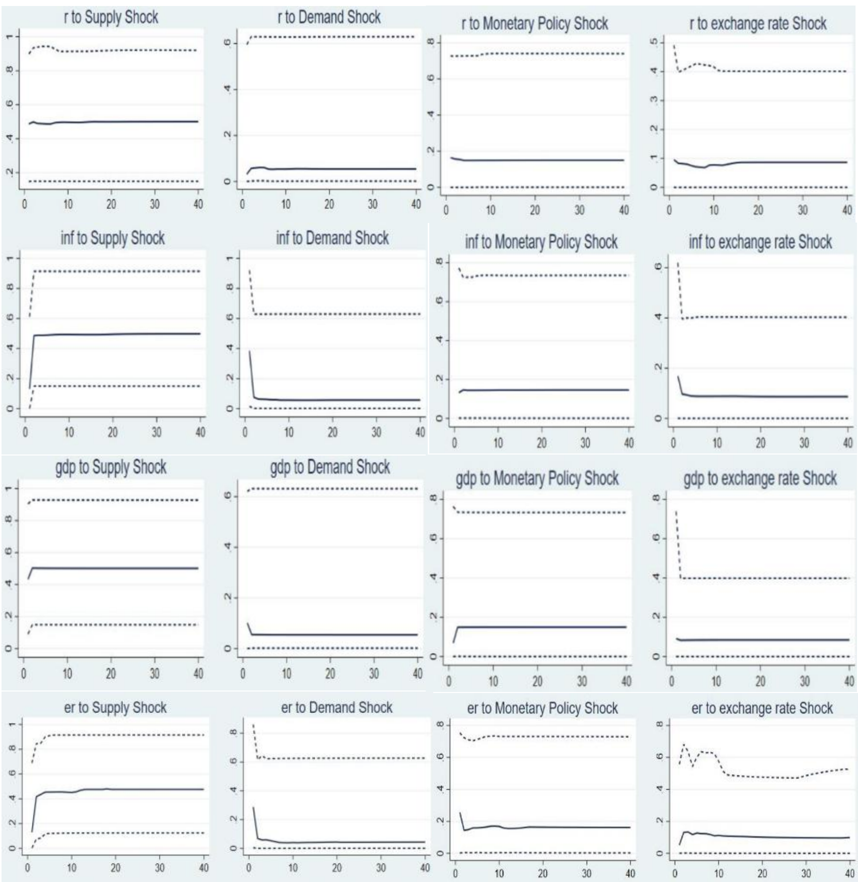

Figure 3. IRFs to 4 shocks identified using SR and BQ approach

Source: *Research finding*

According to Inoue and Rossi (2019), monetary policy leads to the depreciation of the exchange rate. Figure 3 illustrates, consistent with the research by Carrera

& Vergara (2012), that exchange rate shocks account for variations in macroeconomic variables.

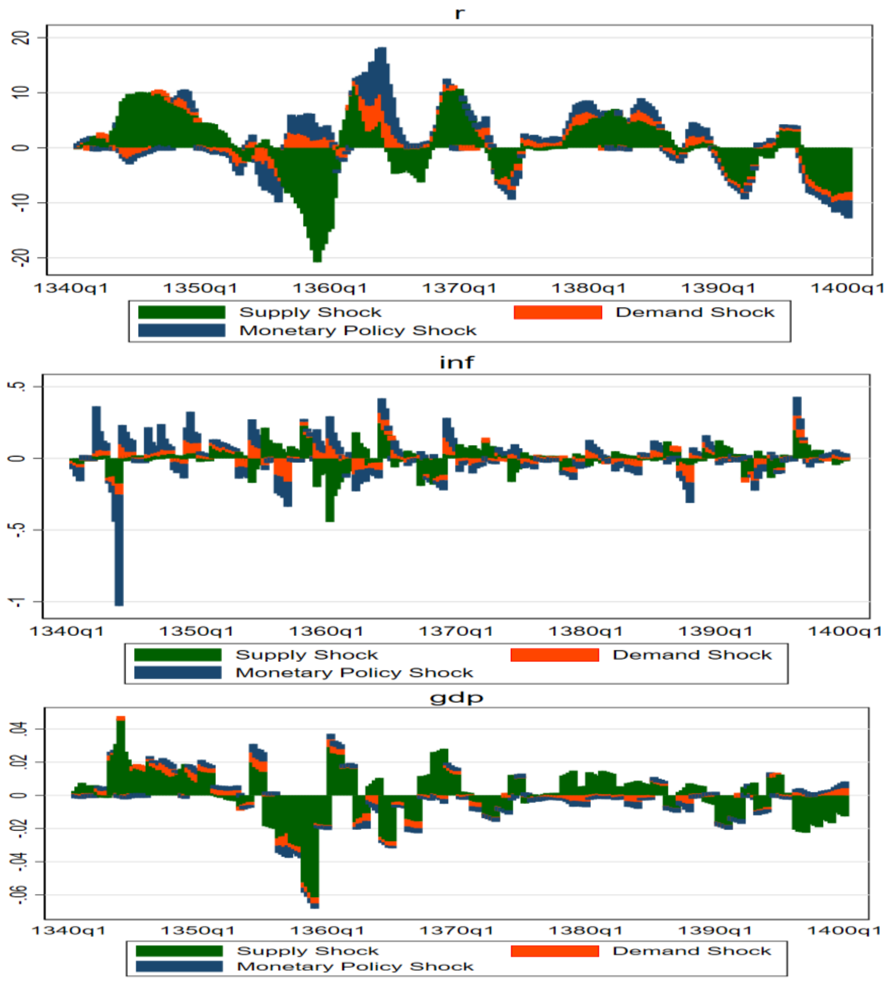

Figure 4: Historical decomposition of three variables

***Source:** Research finding*

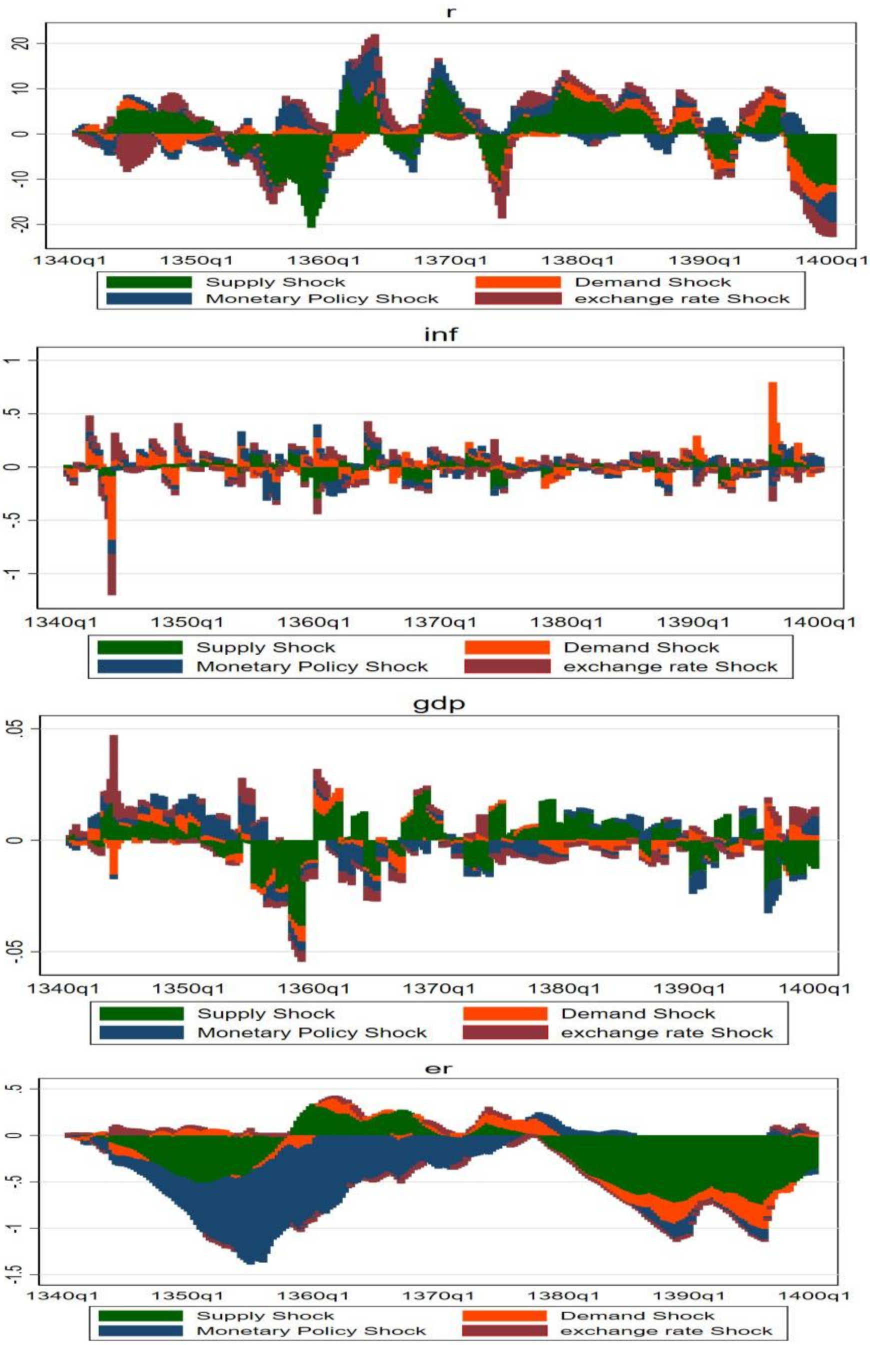

Figure 5. Historical decomposition of four variables

Source: *Research finding*

In accordance with Antolin-Diaz & Rubio-Ramirez (2018), we identified four shocks across two models by employing narrative sign restrictions that constrained the structural shocks (historical decomposition) in relation to significant historical events, assuring alignment with the established narrative of these occurrences. Historical events have significantly influenced r, inf, er, and GDP. The Figures for the chosen historical periods illustrate the unanticipated increase in GDP in the first quarter of 2021, ascribed to monetary policy shocks. The observed rise is depicted in a solid blue hue.

6. Concluding Remarks

Most economists regard unconventional monetary policy as the optimal monetary policy. Nonetheless, inquiries concerning the ideal monetary policy during recessions or financial crises, and the feasibility of identifying unconventional monetary policies analogous to conventional ones, remain unresolved; particularly in instances involving developing nations (e.g., Iran) experiencing economic stagnation. We developed an agnostic identification method to address these concerns, which imposes sign restrictions on demand, supply, exchange rate, and monetary policy shocks by applying zero restrictions on interest rates. Initially, shocks were identified and calculated in the SR, indicating that a negative shock to the interest rate results in an increase in GDP, alongside a reduction in inflation and the exchange rate, stimulating the economy. Subsequently, we examined the impact of zero restriction on the interest rate. The sign pattern employed here aligns generally with the theoretical consensus on the liquidity effect. The liquidity effect posits that a substantial rise in money supply follows a drop in interest rates, subsequently leading to an increase in investment and GDP. Consequently, the findings indicate that:

1) The imposition of negative and zero signs on monetary policy shocks are the principal determinants of unconventional monetary policy shocks; 2) Unconventional monetary policies typically enhance output, mitigate the severity of recessions, and diminish exchange rate volatility by circumventing potential threats to price stability alongside a reduction in inflation; 3) Unconventional monetary policies can assist in preventing substantial risks of GDP contractions. 4) The findings are supported by Ghosh, Ostry, & Chamon (2016), indicating that inflation-targeting central banks in emerging nations effectively pursue (real effective) exchange rate stability alongside interest rate management. 5) The Central Bank of Iran is capable of executing unconventional monetary policy for stimulating the economy more. It necessitates an assessment of the economy's capacity to attain the desired outcomes;

Future researchers could replicate the study by considering Covid-19 as proxy alongside other variables using monthly or quarterly data to provide a more granular understanding of UMP and its impact on Covid-19.

Author Contributions

In all stages of writing the article, including Conceptualization, methodology, validation, formal analysis, preparation of original draft, review and editing, All authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

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Appendix 1

Prior to estimating the model, it is essential to assess the lag length. A preliminary lag length order selection criteria test is conducted for the Initial model, followed by the second model, with results confirming a lag of 2.

Table 1-1. Test for Lag Length Selection (Initial Model)

lags	logL	LR	df	P	FPE	AIC	HQ	SC
0	-217.3	-	-	-	0.0012	1.859	1.876	1.903
1	419.79	1274.2	9	0.000	6.4e-06	-3.441	-3.370	-3.265
2	508.056	176.51	9	0.000	3.3e-06*	-4.110*	-3.986*	-3.802*
3	510.367	4.623	9	0.866	3.5e-06	-4.053	-3.876	-3.614
4	520.263	19.792*	9	0.019	3.4e-06	-4.061	-3.831	-3.490

Source: *Research finding*

Table 1-2. Test for Lag Length Selection (Second Model)

lags	logL	LR	df	P	FPE	AIC	HQ	SC
0	-748.272	-	-	-	0.0067	6.34	6.37	6.40
1	848.278	3193.1	16	0.000	1.1e-08	-6.98	-6.87	-6.69
2	1019.48	342.4*	16	0.000	2.9e-09*	-8.29*	-8.08*	-7.77*
3	1022.73	6.500	16	0.982	3.3e-09	-8.19	-7.88	-7.43
4	1034.74	24.018	16	0.089	3.4e-09	-8.15	-7.75	-7.16

Source: *Research finding*

Table 1-3. Correlation among Four Variables

Variables	r	inf	gdp	er
r	1.0000			
inf	-0.099	1.0000		
gdp	0.244	-0.0816	1.0000	
er	-0.361	-0.0143	-0.1705	1.0000

Source: *Research finding*

Table 1-4. Validity test (Initial Model Utilizing ML Method)

	Coefficient	OIM std. err.	z	$P > \|z\|$	95% conf. interval	
Measurement						
r Factor	1	(constrained)				
_cons	-1.23	0.663	-1.86	0.063	-2.53	0.069
Inf Factor	-0.005	0.004	-1.24	0.215	-0.015	0.003
_cons	0.0111	0.0118	0.94	0.348	-0.012	0.034
gdp Factor	0.0015	0.0013	1.12	0.261	-0.0011	0.0043
_cons	0.008	0.0012	7.07	0.000	0.0064	0.0114
var (e.r)	74.43	29.09			34.605	160.124
var (e.inf)	0.032	0.0031			0.027	0.039
var (e.gdp)	0.0003	0.00007			0.0001	0.0004
var (Factor)	31.52	29.111			5.157	192.64

Source: *Research finding*

Table 1-5. Validity test (Second Model Utilizing ML Method)

	Coefficient	OIM std. err.	z	$P > \|z\|$	95% conf. interval	
Measurement						
r Factor	1	(constrained)				
_cons	-1.23	0.663	-1.86	0.063	-2.53	0.069
Inf Factor	-0.0026	0.0019	-1.36	0.174	-0.0064	0.00117
_cons	0.0111	0.0118	0.94	0.348	-0.012	0.034
gdp Factor	0.0008	0.0003	2.45	0.014	0.0001	0.005
_cons	0.008	0.0012	7.07	0.000	0.0064	0.0114
er Factor	-0.1501	0.057	-2.63	0.008	-0.261	-0.038
_cons	7.305	0.1585	46.09	0.000	6.995	7.616
var (e.r)	45.27	23.003			16.726	122.55
var (e.inf)	0.0334	0.003			0.0279	0.0399
var (e.gdp)	0.0003	0.00003			0.0002	0.0004
var (e.er)	4.687	0.661			3.554	6.1805
var (Factor)	60.683	24.255			27.72	132.83

Source: *Research finding*