“Identifying monetary policy shocks under sign restrictions in Uzbekistan: A robustness reassessment”

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IDENTIFYING MONETARY POLICY SHOCKS UNDER SIGN RESTRICTIONS IN UZBEKISTAN: A ROBUSTNESS REASSESSMENT

Abstract

Counterintuitive responses of prices and exchange rates to monetary policy shocks are widely reported in transitional economies, yet whether these anomalies reflect the economy's structure or the way the shock is identified remains unresolved. Using monthly data from January 2013 to July 2025, we test whether the anomalies survive under agnostic sign restrictions, not previously applied to Uzbek data, benchmarked against the recursive and zero contemporaneous schemes of our earlier studies. The recursive baseline reproduces both anomalies; the alternative schemes remove them, indicating they are largely artefacts of identification. This robustness differs sharply across variables. The absence of a price puzzle holds under sign restrictions across the full sample, alternative lag lengths, and both post-2017 and post-2020 subsamples, and it strengthens after each regime change. The absence of an exchange rate puzzle is directionally consistent – the currency never significantly depreciates when left unrestricted – but its magnitude and significance are fragile: the full-sample appreciation (roughly 1% at 12 months) is several times larger than in either subsample, and it loses significance once the September 2017 liberalization outlier is accounted for. We therefore do not find robust support for the exchange rate channel dominating the price channel. The contribution is methodological rather than descriptive: it shows which conclusions about Uzbek monetary transmission survive a change of identification, and that this robustness itself varies by variable. For policy, the results support continued use of sterilized foreign exchange interventions to smooth volatility, but not robust support for explicit exchange rate targeting.

Keywords exchange rate, interest rate, monetary policy, price puzzle, sign restriction, zero restriction, vector autoregression, inflation

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INTRODUCTION

Quantifying the macroeconomic effects of monetary policy remains a core question for both research and policy. The task is harder in economies undergoing structural transformation, where immature institutions, thin financial markets, and extensive use of foreign currency can alter the routes by which policy reaches prices and the exchange rate (EXCH). In such settings, isolating a genuinely exogenous policy shock is essential for sound interpretation and for effective policymaking.

A common observation in empirical studies is the emergence of counterintuitive reactions of prices and exchange rates to monetary policy shocks in emerging and transitional economies (Rusnák et al., 2013; Elbourne & de Haan, 2006). Specifically, price level rises and EXCH depreciates following a contractionary monetary policy shock, and such responses are difficult to reconcile with standard monetary theory; they complicate the interpretation of vector autoregression (VAR) evidence. A recurring difficulty, however, is that the appearance of

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these anomalies often depends on the identification scheme imposed on the data. The central concern of this paper is therefore not simply to document anomalies, but to establish how sensitive the substantive conclusions about Uzbek monetary transmission are to the choice of identification–an issue that can be settled only by confronting the same dataset with competing identification strategies rather than relying on a single one.

Several features of the Uzbek case make it a particularly informative setting for the current literature. Uzbekistan has recently adopted an inflation-targeting framework, so an accurate account of monetary policy transmission (MPT) carries immediate practical value. The economy is also in the midst of wide-ranging structural change-liberalization of prices and the exchange rate, privatization, and closer integration into world markets-and despite far-reaching reforms to the policy framework and a strengthening of the central bank's legal independence, inflation has stayed elevated. Taken together, these circumstances call for a careful, identification-aware assessment of how the decisions of the Central Bank of Uzbekistan (CBU) transmit to the real economy. This study is part of the authors' broader research agenda on Uzbek monetary policy transmission; its relationship to two previously published papers by the authors, and what is specifically new here, is set out in the Literature review below.

1. LITERATURE REVIEW AND HYPOTHESES

A substantial body of empirical research has extensively examined the dynamic responses of macroeconomic variables to monetary policy shocks. The empirical findings often depend on how the monetary policy shock is identified, especially in emerging and transitional economies. Since the pioneering work of Sims (1980), VAR models have received considerable attention as a modeling approach for transition economies (Elbourne & de Haan, 2006) due to short data series and complex economic interactions, which cast doubt on the reliability of traditional theoretical models (Ganev et al., 2002). Significant progress has been made by researchers who explored various specifications within the VAR framework by incorporating different macroeconomic variables and identification approaches (Sims, 1992; Bernanke & Blinder, 1992; Christiano & Eichenbaum, 1992; Kim & Roubini, 2000; Uhlig, 2005; Peersman, 2005; Gertler & Karadi, 2015).

The crucial aspect of applying the VAR methodology lies in its ability to identify exogenous monetary policy shocks. Various identification strategies may generate counterintuitive results in VAR estimation. Many studies rely on prior economic theories to isolate true monetary policy shocks (e.g., Rotemberg, 1994), arguing that VAR results are meaningful only if the findings align with relevant economic theories. Identifying monetary policy shocks using agnostic procedures has been common in recent years (Canova & De Nicoló, 2002; Uhlig, 2005; Farrant & Peersman, 2006; Scholl & Uhlig, 2008; Kim & Lim, 2018; Pham, 2019). Uhlig (2005) used sign restrictions to identify monetary policy shocks and found that monetary policy affects prices in the long run, supporting the view that monetary policy influences nominal variables in the long run but not real variables. Similarly, Scholl and Uhlig (2008) applied sign restrictions on impulse responses to examine whether monetary policy shocks lead to immediate EXCH fluctuations or delayed overshooting. Moreover, the authors tested how ruling out delayed overshooting changes forward discount puzzle behavior[1]. Two types of restrictions were applied in the study. First, the response of EXCH is left neutral in order to check the delayed overshooting puzzle. Second, delayed overshooting was restricted by construction to evaluate the forward discount puzzle. The results showed that both the delayed overshooting puzzle and the forward discount puzzle were found, and the forward discount puzzle did not disappear even when they restricted the delayed overshooting puzzle.

Several studies examined the ability of sign restrictions in resolving the exchange rate puzzle.

1 Overshooting puzzle occurs when the EXCH reaches a peak after a delay rather than immediately in response to a monetary policy shock. Forward discount puzzle produces a result in which a currency with high interest rates appreciates instead of depreciation, rejecting the Uncovered Interest Rate Parity (UIP) condition.

For example, Jääskelä and Jennings (2011) identified monetary policy shocks by imposing sign restrictions on impulse responses similar to Scholl and Uhlig (2008). An important differential aspect from previous studies is the application of sign restrictions in small open economies working under inflation-targeting regimes. The empirical findings showed that tight monetary policy contributed significantly to appreciation of the EXCH, and delayed overshooting is around 6 months. Importantly, the small open economy features and estimation within a single monetary regime (inflation targeting) addressed puzzling behaviors and found significant EXCH appreciation in response to unexpected monetary policy shocks, confirming Dornbusch's overshooting hypothesis. Similarly, Pham (2019) investigated the effect of monetary policy on EXCH in a transitional economy using agnostic procedures. The author isolated monetary policy shocks from innovations in broad money and used the real effective EXCH. The author suggested that monetary policy shocks identified using agnostic procedures had significant implications for EXCH in Vietnam, supporting Dornbusch's overshooting hypothesis. Overall, sign-restricted VARs can effectively evaluate the impact of monetary policy on the economy and produce results consistent with conventional wisdom.

Alternatively, theory-based zero contemporaneous restrictions have been widely applied in the literature to isolate monetary policy shocks (Sims & Zha, 1998; Kim & Roubini, 2000; Aslanidi, 2007). Sims and Zha (1998), using US data, estimated the VAR model and allowed for the contemporaneous impact of monetary policy on target variables. Monetary policy shocks did not cause substantial changes in output but had a stronger effect on prices. Thus, the observed relationship between high interest rates and low output is not due to contractionary policy but rather reflects high inflationary pressure. Similarly, Kim and Roubini (2000) estimated a VAR model with seven variables using zero contemporaneous restrictions in a group of open economies. The findings revealed that theory-based restrictions were more effective, especially in resolving anomalous behaviors. Following the Kim and Roubini (2000) identification approach, Aslanidi (2007) applied zero contemporaneous restrictions to identify monetary policy shocks in Georgia. The EXCH puzzle was not observed; however, the price adjustment was not reported by impulse response functions (IRFs).

Existing studies generally find the pass-through of monetary policy in Uzbekistan to be limited. Hespeler (2013) applied a vector error correction model (VECM) to assess MPT. The findings showed that the broad monetary aggregate significantly affects gross domestic product (GDP) volatility, while the CBU policy rate did not affect macroeconomic variables. Similarly, Al Rasasi and Cabezon (2022) used a reduced-form VAR model to assess the MPT, and the findings showed that a monetary policy shock had no significant impact on the consumer price index (CPI). Isakova (2008) assessed MPT in Central Asian countries using a reduced-form VAR model. The study found that the EXCH played a significant role in explaining variations in industrial production and CPI. Hespeler's (2013) seminal study used outdated time series data, potentially limiting the relevance of the findings in the current economic context. Additionally, this paper does not examine recent structural changes and modifications in Uzbekistan's monetary policy framework. Similarly, the analysis by Al Rasasi and Cabezon (2022) is limited by a relatively short dataset, comprising only four years of monthly time series data, which may limit the robustness and generalizability of the conclusions.

Overall, the current literature has identified heterogeneity in the reaction of prices and exchange rates to monetary policy shocks, especially in transitional economies. Hence, questions around the puzzles and the identification of the exogenous monetary policy shock remain unsolved, which underscores the need for further analysis in this context.

This study forms part of a broader research objective by the authors on monetary policy transmission in Uzbekistan, and we state that relationship openly. Two related previous studies have already been published. Davlatov and Sági (2026), "Monetary policy transmission mechanism in post-communist economies: Evidence from Uzbekistan", examined the general operation of the transmission mechanism using quarterly data and imposing recursive and zero contemporane-

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ous restrictions. Davlatov et al. (2026), "Resolving price and exchange rate puzzles with the structural VAR model: Evidence from Uzbekistan", addressed the same anomalies using a combination of short- and long-run restrictions. The present study builds directly on this agenda, yet it duplicates neither paper: its research question, its identifying assumptions, and the conclusions are different from both, as set out below and summarized in Table 1.

This study differs from our earlier studies in several important respects. First, in terms of identification, it is the only one of the three to recover monetary policy shocks with an agnostic sign-restriction procedure in the spirit of Uhlig (2005); Davlatov and Sági (2026) identified shocks using recursive and zero contemporaneous restrictions, while Davlatov et al. (2026) combined a hybrid of short- and long-run restrictions. Second, in terms of data frequency and sample, this study uses monthly time series data from January 2013 to July 2025, in contrast to the quarterly 2010–2024 sample of Davlatov and Sági (2026). Third, in terms of variable selection, monetary policy shocks are isolated in the broad money equation in the study of Davlatov and Sági (2026), whereas this study extracts shocks from the interest rate equation. Finally, in terms of contribution, the paper is methodological rather than descriptive: it does not set out to re-document the anomalies but to determine which conclusions about monetary policy transmission in Uzbekistan survive a change in identification and which do not.

A key objective of the study is to assess how robust the empirical conclusions about monetary transmission in Uzbekistan are to the way in which monetary policy shock is identified. To this end, the responses obtained under a recursive baseline are compared with those obtained under agnostic sign restrictions and under theory-based zero contemporaneous restrictions, so that the findings of earlier recursive and zero contemporaneous restrictions can be re-examined within a single framework. Accordingly, the following hypotheses are developed and empirically tested:

H_1: *The recursively identified VAR model tends to generate the price and exchange rate puzzle in Uzbekistan.*

Table 1. Comparison of related studies

Dimension	Davlatov and Sági (2026), Central Bank Review	Davlatov et al. (2026), Post-Communist Economies	Current study
Research question	General functioning of the monetary policy transmission mechanism	Whether the price and exchange rate anomalies can be resolved through a refined identification scheme (a mixture of short- and long-run restrictions)	Whether conclusions about transmission are robust across alternative identification schemes such as sign restrictions
Sample period	2010Q1–2024Q4	January 2013–July 2025	January 2013–July 2025
Data frequency	Quarterly	Monthly	Monthly
Endogenous variables	Real GDP, consumer price index (CPI), broad money (M2), interest rate, real exchange rate, remittances	Industrial production, CPI, monetary aggregate, interest rate, exchange rate	Industrial production, CPI, interbank policy rate, lending rate, reserve money, exchange rate; world commodity price index (exogenous)
Identification strategy	Recursive (Cholesky) and zero contemporaneous restrictions	Recursive baseline with combined short- and long-run restrictions	Recursive baseline, agnostic sign restrictions, and zero contemporaneous restrictions
Exchange rate measure	Real exchange rate	Nominal exchange rate; real effective exchange rate (REER) and nominal effective exchange rate (NEER) in robustness	Nominal bilateral rate (UZS/USD); real effective exchange rate in robustness
Estimation framework	SVAR	SVAR	SVAR
Robustness analysis	Alternative specifications	Different lags, alternative monetary aggregates, REER/NEER, subsamples	Alternative lag lengths; real effective exchange rate; two sign-restriction scenarios
Main contribution	Documents weak transmission and a more effective exchange rate channel	Resolves the anomalies via a mixed short-/long-run restriction scheme	Tests the robustness of those conclusions under agnostic sign restrictions and shows the exchange rate response is endogenous

H_2: *The anomalies produced by the recursive scheme are not robust to identification; they are substantially attenuated or removed once the monetary policy shock is identified under alternative, theory-consistent schemes.*

H_3: *The sign restrictions and the theory-based zero contemporaneous restrictions are able to resolve the price and the exchange rate puzzle.*

2. METHODS

The objective of this study is to estimate the dynamic causal effect of monetary policy on output, prices, and EXCH. This objective can be achieved using structural vector autoregression (SVAR) models. The economy is described with the following structural equation:

$$A_0 Y_t = d + \sum_{j=1}^{p} A_j Y_{t-j} + \sum_{i=1}^{q} B_i X_{t-i} + u_t, \quad (1)$$

where Y_t is the vector of endogenous variables, d is a deterministic component that is perfectly forecastable and can be omitted as such, and X_t is the vector of exogenous variables. A_0 describes the contemporaneous relations among variables. A_j and B_i are coefficient vectors. u_t is the nx1 – dimensional vector of shocks: $u_t \sim$ WN(0, Ω) where Ω is a diagonal matrix. Next, the model needs to be converted into a vector moving average representation (VMA) to estimate the parameters. However, SVAR parameters cannot be directly estimated due to the simultaneity problem. To estimate the parameters, the SVAR model in equation 1 can be written in its reduced-form representation. This is achieved by multiplying both sides by $A_0^{-1,}$ and the following reduced-form equation is obtained:

$$Y_t = c + \sum_{j=1}^{p} a_j Y_{t-j} + \sum_{i=1}^{q} \beta_i X_{t-i} + \varepsilon_t, \quad (2)$$

where, $\alpha_j = A_0^{-1} A_j$, $c = A_0^{-1} d$, $\beta_i = A_0^{-1} B_i$, $\varepsilon_t = A_0^{-1} u_t$, $A_0^{-1} A_0 = I$.

Now, the reduced form VAR is covariance-stationary, then it can be expressed in its VMA representation using the Wold theorem, hence:

$$Y_t = C(L)\varepsilon_t, \quad (3)$$

where $C(L) = I + C_1 L + C_2 L^2 + \ldots$ are the Wold impulse response functions, and $\varepsilon_t \sim WN(0, \Sigma)$. Hence, equation (3) is equivalent to:

$$Y_t = \sum_{h=0}^{\infty} C_h \varepsilon_{t-h}. \quad (4)$$

Then, the effect of a shock h periods ahead on variables (IRF) can be written as follows:

$$IRF = \frac{\partial Y_{t+h}}{\partial \varepsilon_t}, \quad (5)$$

A monetary policy shock needs to be purely exogenous, meaning that it should not be the reaction of a central bank to movements of other economic variables. If a monetary policy change is due to the expected set of events in the economy, the monetary policy shock is considered endogenous. In this scenario, the impact of monetary policy on other variables cannot be directly identified, and it is not the correct way of measuring it. To measure the impact of a monetary policy shock accurately, it is essential to isolate purely independent or exogenous shocks to monetary policy and observe how the exchange rate and prices react to them. To isolate a purely exogenous monetary policy shock, this study imposes sign restrictions and theory-based zero contemporaneous restrictions.

The baseline model includes six endogenous variables, and the ordering of variables follows economic reasoning. There is no clear consensus on how to order variables in the SVAR system. Following the ordering scheme for small open economies (Bernanke & Blinder, 1992; Peersman & Smets, 2001; Pham, 2019), the functional form of the baseline model is expressed in Equation (6).

$$Y_t = \left(IP_t, CPI_t, PR_t, LR_t, M_t, EXCH_{t,} \right). \quad (6)$$

Industrial production (IP_t) is a proxy variable for output, and the consumer price index (CPI_t) for the price level. The rest of the variables are the financial variables: PR_t is the short-term interbank rate as a monetary policy variable, LR_t is the short-term lending rate, M_t is reserve money, and $EXCH_t$ is the EXCH of the Uzbek sum relative to the US dollar. The reason for ordering monetary

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variables after economic variables is that the monetary authority can observe the macroeconomic conditions in the current period. This approach assumes that monetary policy decisions affect real sector variables with lags in the Cholesky scheme. The system also includes the world commodity price index (WCP_t) to assess external shocks on the domestic economy. To mitigate the risk of over-parameterization arising from a limited sample, the study incorporated only a single external variable.

The matrix below presents the contemporaneous coefficient structure of the recursive model:

Table 2. Cholesky-based restriction framework

Y_{ij}	IP	CPI	PR	LR	M	EXCH
IP	a_{11}	0	0	0	0	0
CPI	a_{21}	a_{22}	0	0	0	0
PR	a_{31}	a_{32}	a_{33}	0	0	0
LR	a_{41}	a_{42}	a_{43}	a_{44}	0	0
M	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	0
EXCH	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	a_{66}

Rows one and two are the real sector block, which consists of IP and CPI. Rows three, four, and five capture monetary sector variables PR, LR, and M, reflecting the equilibrium in the money and credit markets. Row six shows the equilibrium in the EXCH market. IP is not impacted contemporaneously by other shocks in the system by construction in the Cholesky order; however, a shock to IP affects other variables in the current period. The PR equation is a reaction function of the monetary authority. This variable reacts contemporaneously to shocks in IP and CPI; however, a shock to monetary policy does not affect IP and CPI in the current period. An EXCH shock does not affect other variables in the current period. This assumption is the subject of considerable debate; therefore, the assumptions of the recursive scheme are omitted in alternative models.

Since the recursive ordering imposes timing constraints that are open to question, the second identification scheme replaces them with restrictions based on signs of the impulse responses, following the agnostic procedure of Uhlig (2005). The identifying logic is that, on theoretical grounds, a contractionary monetary policy shock should raise the interbank policy rate and the commercial lending rate, reduce reserve money, and lead the domestic currency to appreciate. These directional restrictions are given in Table 3. A key feature of this approach is that sign restrictions constrain only the direction of selected responses and leave their magnitude and persistence to be determined by the data; therefore, this agnostic procedure embodies substantially weaker identifying assumptions than either the recursive or the zero contemporaneous scheme.

Two scenarios are examined in order to distinguish the assumptions that drive the results from the genuinely informative responses. In the first scenario, the responses of industrial production and the price level are left unrestricted, so that the direction of the output and inflation reactions is an outcome of estimation rather than of assumption. In the second scenario, the restriction on the exchange rate is removed – and the price level is restricted instead – so that the exchange rate response is left entirely free. This design informs directly of the concern that a large exchange rate reaction might be an artefact of the identifying restrictions: if the currency still appreciates when the exchange rate is left unrestricted, its response is endogenous rather than imposed by construction. In implementation, candidate structural impulse vectors are drawn and retained only when they satisfy every imposed sign restriction, while draws that violate any restriction are discarded.

The monetary policy shock is identified with the rotation algorithm of Rubio-Ramírez et al. (2010), implemented with the VAR Toolbox 3.0 for MATLAB (Cesa-Bianchi, n.d.). In each iteration, the coefficients and the residual covariance matrix Σ of the reduced-form VAR are drawn from their Normal–inverse-Wishart posterior under a diffuse prior, and a candidate impact matrix PQ is formed, where P is the lower Cholesky factor of Σ and Q is a random orthogonal matrix obtained from the QR decomposition of a 6×6 matrix of independent standard normal draws. A column of PQ, or the same column multiplied by –1, is accepted as the monetary policy shock only if all restrictions in Table 3 hold on impact and in each of the following five months (h = 0, …, 5); responses from the sixth month onward are unrestricted. Up to 500 rotations are tried for each posterior draw,

Table 3. Sign restrictions: positive 1, negative -1, unrestricted 0

Shock	Scenario 1					
	IP	**CPI**	**PR**	**LR**	**M**	**EXCH**
Monetary policy shock	0	0	1	1	–1	–1
	Scenario 2					
	IP	**CPI**	**PR**	**LR**	**M**	**EXCH**
	0	–1	1	1	–1	0

and the procedure stops when 500 draws have been accepted. In the baseline model, 1,147 candidate rotations were required in Scenario 1 and 2,299 in Scenario 2 (acceptance rates of 43.6% and 21.7%), and no posterior draw had to be discarded. The accepted shock is normalized to be contractionary (a non-negative policy-rate response) and to have a size of one standard deviation. The reported impulse response is the pointwise median of the 500 accepted responses, and the 68% bands are their pointwise 16th and 84th percentiles; because each accepted draw combines a posterior draw of the reduced-form parameters with an admissible rotation, the bands reflect both estimation uncertainty and the identification uncertainty inherent in a set-identified model, and no bootstrap is used for this step. As the bands combine responses from different admissible models and depend on the uniform prior over rotations, they are posterior summaries rather than frequentist confidence intervals (Fry & Pagan, 2011; Baumeister & Hamilton, 2015); as a check, the median-target model of Fry and Pagan (2011) nevertheless lies within the reported band at all 36 horizons for the CPI response in Scenario 1 and the exchange rate response in Scenario 2. The random seed is fixed (12345), so that all results can be reproduced exactly; the replication code is available from the authors.

Following Kim and Roubini (2000) and Elbourne and de Haan (2006), theory-based zero contemporaneous restrictions are also imposed. Empirical literature suggests that theory-based zero contemporaneous restrictions are considered an efficient approach to identify monetary policy shocks (Rusnák et al., 2013). Identifying monetary policy imposing zero contemporaneous restrictions tends to produce IRFs that align with conventional wisdom. Thus, the following matrix presents the contemporaneous relationships of the variables.

IP is assumed to be fully exogenous, meaning that it does not react to other shocks contemporaneously in the system. IP has a contemporaneous effect on prices and the exchange rate but on no other variables. Moreover, the price level is affected by an EXCH shock in the current month. This assumption is consistent with the high import-dependent feature of Uzbekistan. The third equation is the monetary policy reaction function, in which the CBU can observe credit conditions, reserves, and the EXCH market before the decision-making process. Therefore, LR, M, and EXCH are contemporaneous in the monetary policy equation. The commercial bank interest rate depends not only on reserves but also on funds in foreign currency, so these two variables contemporaneously influence the commercial bank interest rate. Additionally, the EXCH has a contemporaneous effect on LR due to depreciation expectations in banks, while reserves are affected by LR and EXCH shocks. Lastly, the EXCH responds to all shocks in the current month, following the original specification in Kim and Roubini (2000). The system has a total of sixteen restrictions to estimate, which makes it an over-identified structure.

$$\begin{bmatrix} \varepsilon_{IP} \\ \varepsilon_{CPI} \\ \varepsilon_{PR} \\ \varepsilon_{LR} \\ \varepsilon_{M} \\ \varepsilon_{EXCH} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & a_{26} \\ 0 & 0 & 1 & a_{34} & a_{35} & a_{36} \\ 0 & 0 & 0 & 1 & a_{45} & a_{46} \\ 0 & 0 & 0 & a_{54} & 1 & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \cdot \begin{bmatrix} \mu_{IP} \\ \mu_{CPI} \\ \mu_{PR} \\ \mu_{LR} \\ \mu_{M} \\ \mu_{EXCH} \end{bmatrix}. \quad (7)$$

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The Statistical Committee of Uzbekistan, the CBU, and the IMF are the main sources of the collected data. The selected variables span from January 2013 to July 2025. The process of data collection is not easy because of the limited data availability. IP, CPI, PR, LR, M, and EXCH are endogenous variables, while WCP and two structural dummies that reflect the exchange market liberalization in 2017 and the shift to a new inflation targeting regime are exogenous variables. The summary statistics are presented in Table A1 Appendix A. Additionally, unit root tests were conducted to determine the integration of variables using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests, and the results are given in Table A2 Appendix A. Following Sims et al. (1990), the seasonality effects are adjusted, and all variables are converted into logarithms (except interest rates), and the model is estimated in levels. The Akaike information criterion (AIC) showed lag order two, and all roots of the recursive (Cholesky) model are strictly inside the unit circle (largest root 0.995; Figure A1 Appendix A); the sign-restricted model, which is estimated without a separate intercept, has a largest root of 1.002, essentially on the unit circle.

Because the sample covers both the September 2017 exchange-market liberalization and the January 2020 transition to inflation targeting, the stability of the model was tested formally at both dates. Likelihood-ratio tests in which the respective break dummy is interacted with all lagged endogenous variables and the world commodity price index reject the constancy of the autoregressive coefficients (wild-bootstrap $p \leq 0.001$ at both dates), and Chow break-point tests reject the joint constancy of the coefficients and the residual covariance matrix (bootstrap $p < 0.001$; Appendix B). The structural dummies therefore capture level shifts, but not changes in the dynamics, and the full-sample estimates should be read as averages across policy regimes. To examine whether the identified responses themselves depend on the regime, the sign-restricted model was re-estimated on the post-liberalization (2017M09–2025M07) and post-transition (2020M01–2025M07) subsamples with identical restrictions (Appendix C). In both subsamples, the price level falls significantly when it is left unrestricted, so the absence of a price puzzle does not depend on pooling the regimes and, if anything, strengthens after each break. The exchange rate also appreciates in both subsamples when it is left unrestricted, but the appreciation is considerably smaller than in the full sample (0.15-0.18% versus 1.03% at 12 months) and significant only from month 19 and month 11, respectively. Because the subsample VARs estimate 14-15 coefficients per equation from only 65-93 monthly observations, these subsample estimates are less reliable than the full-sample results and are interpreted as evidence on the direction, rather than the magnitude, of the responses. The September 2017 liberalization also deserves separate attention because it is not merely a regime break but a one-off jump in the level of the exchange rate: the corresponding residual is 10.5 standard deviations in the exchange rate equation, far larger than a step dummy can absorb. When this single observation is additionally captured with an impulse dummy (full sample, otherwise identical model), the Scenario 1 conclusion is unaffected – the price level still shows no significant increase – but the Scenario 2 exchange rate appreciation falls from 1.03% to 0.08% at 12 months, and its 68% band now contains zero at every horizon. At 12 months the point estimate remains an appreciation in every specification we examined – the full sample, both subsamples, and the full sample with this impulse dummy – and a significant depreciation is never found; but its statistical significance and its economic magnitude depend materially on how this single month is treated. We therefore draw a more cautious conclusion than for the price puzzle: the absence of a price puzzle under sign restrictions appears robust across specifications, whereas the resolution of the exchange rate puzzle is directionally consistent but not robust to controlling for the 2017 liberalization episode, and the claim that the exchange rate channel dominates the price channel is not supported once this is taken into account.

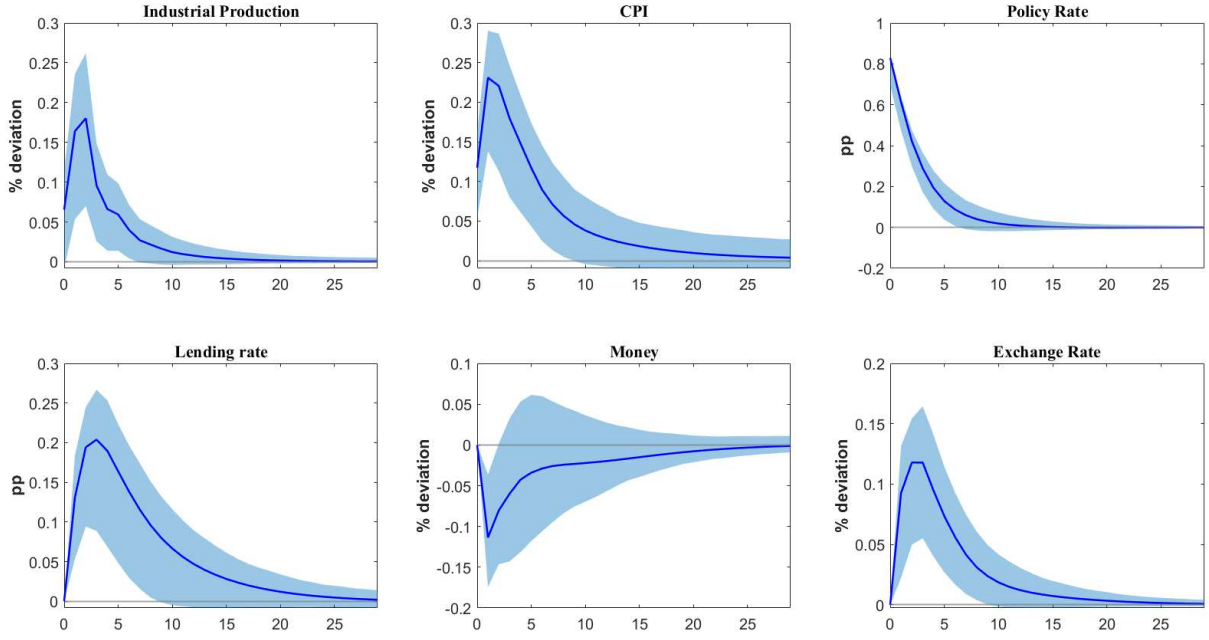
3. RESULTS

A critical principle for evaluating the validity of empirical models lies in the direction, strength, and magnitude of responses to monetary policy shocks. Therefore, this study focuses on the IRFs of key economic variables to monetary policy shocks, emphasizing the strength, magnitude,

and significance of responses. The Cholesky baseline and the theory-based zero contemporaneous model reproduce identification schemes already used in our earlier studies of Uzbekistan and are reported here to establish a common benchmark; the results obtained under agnostic sign restrictions, an identification strategy not previously applied to Uzbek data, constitute the incremental methodological contribution of this paper. The baseline model estimation based on Cholesky decomposition is presented initially, followed by the alternative model results.

Figure 1 presents the impulse responses of IP, CPI, M and EXCH to a one-standard deviation monetary policy shock. Interest rates are retained in levels so they can be interpreted as percentage points. In this baseline model, the monetary policy shock is isolated from PR innovations. Following an unexpected monetary policy shock, IP rose, indicating an expansionary effect in the first month. Specifically, IP rose by approximately 0.18% in the first month following a one-standard-deviation monetary policy shock. Nevertheless, this upward trend was short-lived. Following this, IP started to reverse to the baseline level from the second month and stood about 0.007% above the baseline level in month fifteen. This tendency persisted up to the twenty-fifth month, after which the shock gradually dissipated. The IP dynamic response was statistically significant for roughly the first nine months. The IP response to the monetary policy shock is marginally small in the medium and long terms, and it is contradictory to existing theories. Such a phenomenon is extensively found in empirical studies, especially those focusing on low-income and transitional economies (Mishra & Montiel, 2013).

Following an unexpected monetary policy disturbance, CPI initially increased by 0.11% on impact. After that, the CPI attained a peak of 0.23% in the second month. Then, CPI fell gradually, and the magnitude of the response declined over the longer horizon, reaching 0.01% in month twenty. It eventually returned to the original level by the twenty-eighth month. The impact response of CPI is statistically significant; however, the response is not in the expected direction, and it is known as the *price puzzle*.



Note: Impulse responses of industrial output, price level, policy and lending rates, reserve money and EXCH to a one-standard-deviation monetary policy shock, isolated via Cholesky factorization. Shaded areas denote the 68% error bands using bootstrap sampling. Some variables are log-transformed, and the VAR is estimated in levels. Industrial production, CPI, money, and exchange rates are interpreted as percentage deviations from the baseline, and the policy interest rate and lending rate are expressed in percentage points. Since the exchange rate is quoted as Uzbek sum (UZS) per USD, an increase shows a depreciation of UZS while a decline indicates an appreciation of UZS.

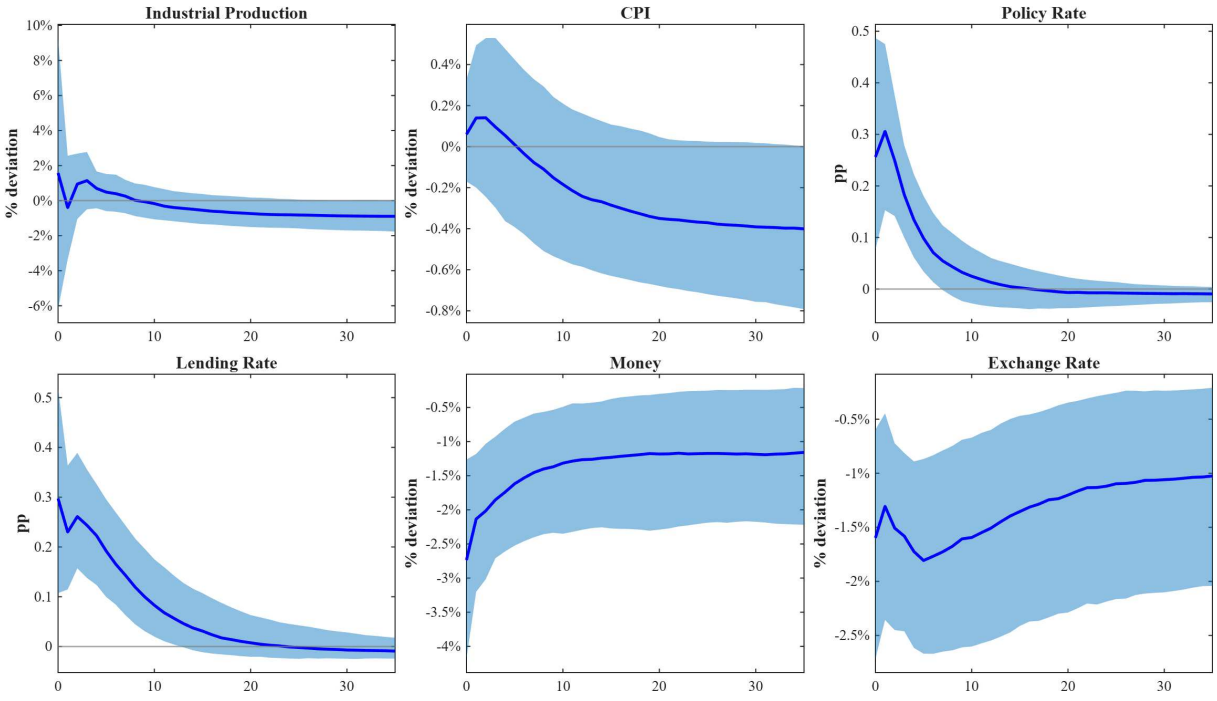
Figure 1. Impulse responses to monetary policy shock

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The third column presents the IRF of the EXCH to a one-standard-deviation monetary policy shock. Notably, the EXCH is quoted directly; therefore, a positive monetary policy shock led to a nominal depreciation of the Uzbek sum against the U.S. dollar, which is contrary to the predictions of conventional theories. Specifically, a onestandard-deviation monetary policy shock caused a 0.09% depreciation in the first month and reached a peak of 0.12% in the second month. Following the initial depreciation, the EXCH started to decline over the subsequent twenty-four months and returned to the steady-state level in month twenty-eight. Overall, IRFs confirmed the first hypothesis that the recursive scheme tends to generate both the price and exchange rate puzzle. Such puzzling behaviors necessitated employing alternative restrictions to identify the exogenous monetary policy shock. Notably, the lending rate responded positively to the monetary policy shock while reserve money declined in the short run. Both responses aligned with conventional theories and were statistically significant.

Next, forecast error variance decomposition (FEVD) analysis was conducted to assess the contribution of each shock to forecast uncertainty (Figure A2 Appendix A). LR and M shocks explain the sizable fluctuations of CPI and EXCH after their own shocks.

The short-run restrictions based on Cholesky decomposition generated both the price and the EXCH puzzles that cast doubt on the empirical validity of the baseline model. Therefore, following Uhlig (2005) and Ha et al. (2025), an alternative approach imposing sign restrictions was employed to identify the true monetary policy shock. There are two reasons for the application of sign restrictions. First, short-run restrictions produced puzzles. Second, the Cholesky order is not able to capture the true relationship between monetary policy and the EXCH dynamics in Uzbekistan. As the EXCH comes last in the recursive system, the EXCH has no contemporaneous effects on the other variables. The EXCH has been an important barometer of Uzbekistan's economy, especially be-



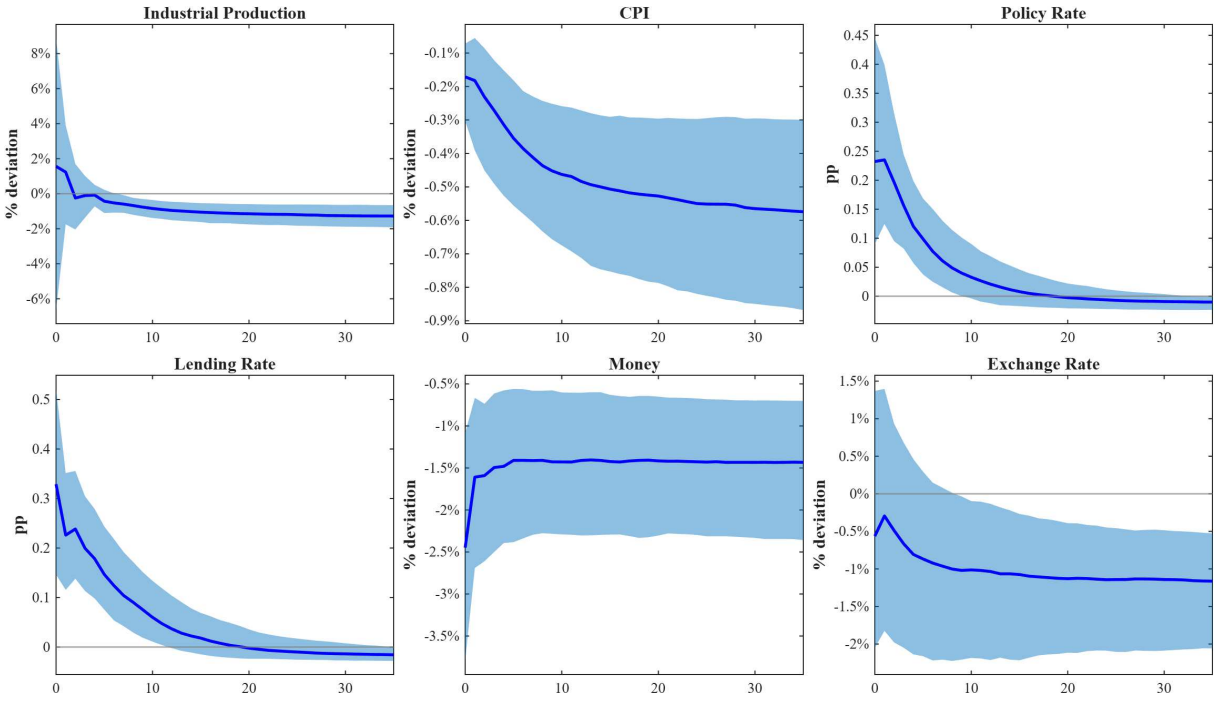
Note: The impulse responses of industrial output, price level, policy and lending rates, reserve money and EXCH to a one-standard-deviation monetary policy shock, isolated imposing sign restrictions. The blue line is the pointwise median and the shaded area the 68% band (pointwise 16th and 84th percentiles) of the 500 accepted responses. Some variables are log-transformed, and the VAR is estimated in levels. Industrial production, CPI, money, and exchange rates are interpreted as percentage deviations from the baseline, and policy interest rate and lending rate are expressed in percentage points. Since the exchange rate is quoted as UZS per USD, an increase shows a depreciation of UZS while a decline indicates an appreciation of UZS.

Figure 2. Impulse responses to monetary policy shock

fore the liberalization of the EXCH market in 2017. The recursiveness assumption overlooks such a reality; therefore, it is weak in reflecting the true dynamics between monetary policy and the EXCH.

Figure 2 presents the IRFs of the alternative model imposing sign restrictions. The restrictions are derived from Table 3 (scenario 1), in which the IP and CPI are left unrestricted, and other variables are imposed with theory-based sign restrictions. The monetary policy shock affected IP after month eight in a consistent direction with most theories, but it is not statistically significant. Additionally, the magnitude of the IP response is larger in the long run. M and the EXCH fell and LR rose, as imposed by the sign restrictions. Although the price level responded positively in the first month, it started to decline after the second month. CPI then fell steadily, reaching negative 0.24% after a year and a trough of 0.4% in the long run. Importantly, the direction of the CPI response is consistent with current economic theories; however, it is not statistically significant. The insignificant response of prices to monetary policy shock demonstrates that monetary policy transmission is still in a transitional stage. Various structural factors are discussed in the literature to explain such puzzles in Uzbekistan (Poghosyan et al., 2023). Because the exchange rate is restricted to appreciate by construction in this scenario, only the CPI response is informative about the price puzzle here: on that basis, the price puzzle does not survive when the shock is identified via sign restrictions rather than recursive ordering, consistent with the second hypothesis that puzzling behaviors reflect misidentification of the true monetary policy shock rather than structural factors in the economy. The exchange rate puzzle is addressed separately, under Scenario 2, in which the exchange rate is left unrestricted.

Figure 3 presents the IRFs of variables to a one-standard-deviation monetary policy shock identified, imposing sign restrictions derived from Table 3 (scenario 2). The sign restrictions are imposed on PR, LR, M, and CPI but leave EXCH unrestricted



Note: The impulse responses of industrial output, price level, policy and lending rates, reserve money and EXCH to a one-standard-deviation monetary policy shock, isolated by applying sign restrictions. The blue line is the pointwise median and the shaded area the 68% band (pointwise 16th and 84th percentiles) of the 500 accepted responses. Some variables are log-transformed, and the VAR is estimated in levels. Industrial production, CPI, money, and exchange rates are interpreted as percentage deviations from the baseline, and policy interest rate and lending rate are expressed in percentage points. Since the exchange rate is quoted as UZS per USD, an increase shows a depreciation of UZS while a decline indicates an appreciation of UZS.

Figure 3. Impulse responses to monetary policy shock

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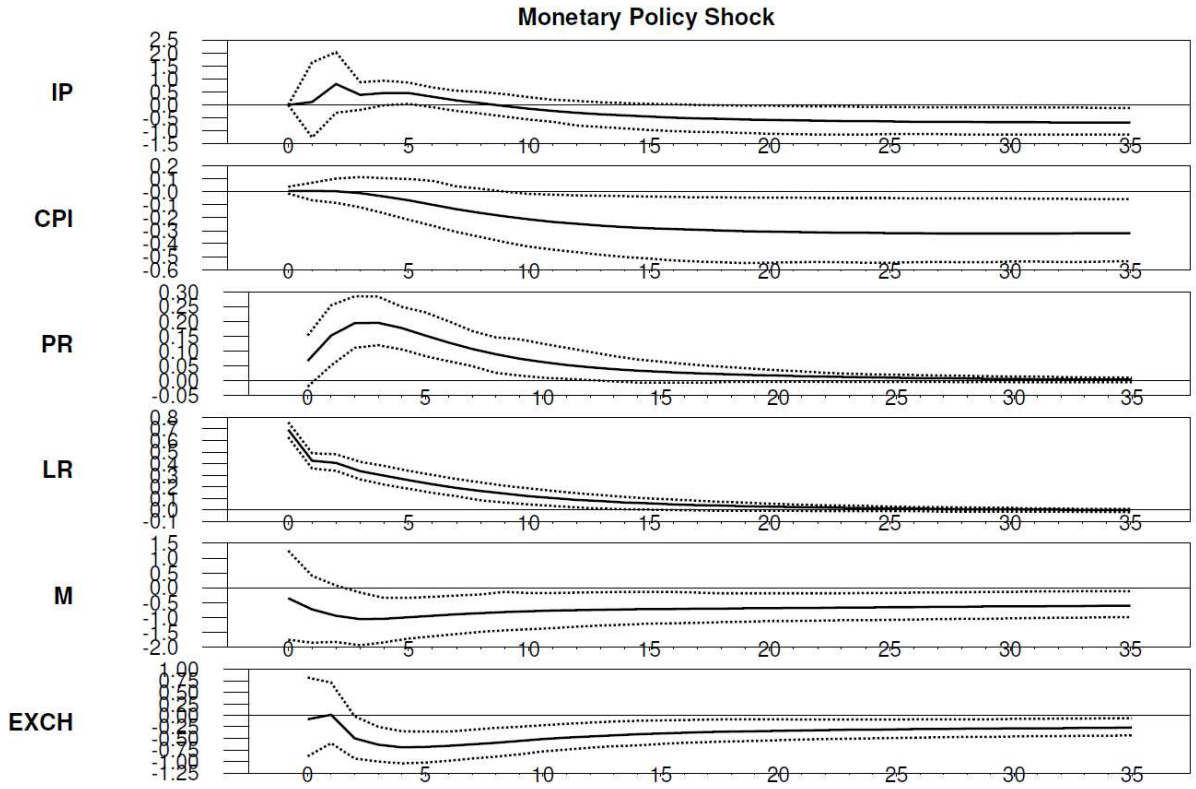
to assess the dynamic response of EXCH to monetary policy. IP was above the baseline in the beginning but fell below it from the second month, exhibiting a peak deviation of approximately 1.3% at month thirty. IP reaction was statistically significant in the medium and long run.

The EXCH had a sudden appreciation on impact followed by a rapid partial reversal in the very short run. Thereafter, it gradually appreciated in the medium term, and it reached 1.03% at month twelve, strengthening only slightly thereafter. Because the exchange rate is deliberately left unrestricted in this scenario (Table 3), its appreciation is not imposed by the identifying assumptions but arises endogenously from the estimated dynamics, which addresses the concern that the direction of the result might be mechanically built into the identification. The large magnitude reported here, however, should be read with caution: as detailed in the Methods section, it shrinks several-fold in both post-break subsamples and loses statistical significance once the September 2017 liberalization outlier is separately controlled for, so it appears to be a property of the full-sample estimate rather than a stable feature of the transmission mechanism. As in many transitional economies, a sizeable share of banking-sector balance sheets in Uzbekistan is denominated in foreign currency – about 25% of deposits and 42.9% of loans in January 2025 – and this currency substitution tends to blunt the pass-through of policy decisions[2]. In the full sample, the reaction of the EXCH is larger and more significant than the CPI response in this alternative identification; as discussed below, however, this comparison does not hold up once the sample is split around the 2017 and 2020 regime changes or once the 2017 liberalization outlier is separately controlled for, so it should not be read as establishing a generally more efficient EXCH channel. Because the CPI response is imposed by construction in this scenario, this result speaks to the exchange rate puzzle rather than the price puzzle: the median exchange rate response still appreciates even when its sign is left free, and it is statistically significant from month 9 onward in the full sample, consistent with the second hypothesis. As discussed in the Methods section and revisited in the Discussion, however, this appreciation is far smaller and only marginally significant once the sample is split around the 2017 and 2020 regime changes, and it loses significance altogether once the September 2017 liberalization residual is separately accounted for; the 12-month point estimate never reverses sign, but we treat the resolution of the exchange rate puzzle as considerably less robust than that of the price puzzle.

Following Kim and Roubini (2000), the monetary policy shock was identified by imposing the theory-based zero contemporaneous restrictions. The motivation for applying zero contemporaneous restrictions is due to its ability to resolve puzzles in advanced and emerging economies.

The VAR system includes the same variables as used in the baseline model, and the lag number two is selected relying on the AIC. Figure 4 summarizes the IRFs results derived from the restrictions in Equation 7. PR and LR reacted positively and significantly following a contractionary monetary policy shock. The impact response of LR is larger than that of PR in terms of magnitude. The trend of PR persisted for three months before gradually reversing, while LR immediately returned after the rise. The immediate reaction of interest rates to a monetary policy shock is consistent with the interest rate channel in the framework of New Keynesian models (Woodford, 2003). This indicates that the first stage of the monetary transmission mechanism is in operation in Uzbekistan. CPI had a marginal positive response to a contractionary monetary policy shock in the very short run, which is consistent with the results of sign restrictions in the previous section. However, the shock induced a steady decline in CPI after the third month, reaching a peak of –0.2% in month ten. This trend persisted in the medium term, reaching a maximum deviation of –0.3% in month twenty. This disinflationary effect of monetary policy aligns with conventional theories of monetary policy. The EXCH appreciated instantaneously by roughly 0.1% on impact, and this appreciation reached a trough of 0.7% in month five. Then, the response was characterized by overshooting,

2 Deposit and credit dollarization are measured as the share of foreign currency-denominated deposits and credits in total deposits and credits. The corresponding data are available from the Statistical Bulletin of the Central Bank of the Republic of Uzbekistan (Central Bank of the Republic of Uzbekistan, 2024).



Note: Impulse responses of industrial output, price level, policy and lending rates, reserve money and EXCH to a one-standard-deviation monetary policy shock, isolated via zero contemporaneous restrictions. Dashed lines denote 68% error bands using Monte Carlo integration (importance sampling). Some variables are log-transformed, and the VAR is estimated in levels. Industrial production, CPI, money, and exchange rates are interpreted as percentage deviations from the baseline, and policy interest rate and lending rate are expressed in percentage points. Since the exchange rate is quoted as UZS per USD, an increase shows a depreciation of UZS while a decline indicates an appreciation of UZS.

Figure 4. Impulse responses

aligning with Dornbusch's (1976) hypothesis and empirical evidence in Christiano et al. (1999). The magnitude of the EXCH response was more pronounced than the adjustment of prices in response to a monetary policy shock, aligning with previous results. Thus, the theory-based zero contemporaneous restrictions effectively solved both the price and the EXCH puzzles.

The robustness analysis is carried out for the sign-restricted model and the zero contemporaneous model to confirm the validity of the results. The model results are compared by changing the lag length. For example, the sign-restricted model is analyzed with lag three, and the IRF results are given in Figures A3 and A4 Appendix A. Figure A3 Appendix A presents IRFs derived from the restrictions of scenario 1 in Table 3. CPI rose on impact following a contractionary monetary policy; however, it persistently declined, reaching -0.1% after a year and -0.3% in the long term. The response of CPI is not statistically significant at any horizon. Figure A4 Appendix A shows the IRFs for scenario 2 restrictions in Table 3. The EXCH appreciated immediately by roughly 0.8%, and it became strong in the medium and long term. Changing the lag length confirmed the baseline model results with sign restrictions. Moreover, a similar test for zero contemporaneous restrictions was also conducted. The new model is estimated with lag number three, and IRFs are given in Figure A5 Appendix A. The reaction of CPI is negative in the medium and long term in response to an unexpected monetary policy disturbance, though the shock induced an immediate increase in prices of approximately 0.1% in the first month. Similarly, the EXCH appreciated by around 0.2% on impact and weakened slightly over the next two months, but the effect was transitory, as appreciation dominated from the third month onwards. The magnitude of the EXCH response was larger than that of CPI to the monetary policy shock,

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reaching a peak of 0.7% in the eighth month. Hence, the results not only confirmed the baseline model but also the results of the sign-restricted model. Overall, both models are not sensitive to lag changes and confirm the reliability across different lags. Furthermore, the real effective EXCH was employed instead of the nominal EXCH as an alternative test for robustness. The model results are found to be consistent with the baseline model without generating anomalies.

Taken together, the results support H_1: the recursively identified model generates both the price and the exchange rate puzzle. H_2 is supported for the price level, because the price puzzle is absent under the alternative schemes across lag lengths and in both subsamples; for the exchange rate it is supported in direction only, because the appreciation loses significance once the September 2017 liberalization outlier is controlled for. H_3 is supported in the full sample: the theory-based zero contemporaneous restrictions resolve both puzzles, and the sign restrictions remove each puzzle in the scenario in which the variable concerned is left unrestricted, subject to the same caveat for the exchange rate.

4. DISCUSSION

The baseline model identified monetary policy shocks using Cholesky factors, in which the order of the variables is important. IRFs of the baseline model showed puzzling behaviors of variables. The IP response to the monetary policy shock is marginally small in the medium and long term, and it is contradictory to existing theories, and such a phenomenon is extensively found in empirical studies, especially those focusing on low-income and transitional economies (Mishra & Montiel, 2013). Moreover, the price puzzle is observed in response to monetary policy shocks. Such puzzling behavior of prices is prevalent in empirical studies (Ganev et al., 2002; Nwosu et al., 2019; Al Rasasi & Cabezon, 2022; Davlatov et al., 2026). Similarly, the EXCH puzzle was observed over the whole period in the baseline model, which is well documented in the studies by Grilli and Roubini (1995), Eichenbaum and Evans (1995), and Kohlscheen (2014). VAR literature has documented various reasons for puzzling behaviors when a monetary policy shock is identified using a recursive scheme. According to Christiano et al. (1999), a VAR structure that omits forecasting variables tends to exhibit anomalies. Hence, adding forward-looking variables is common in resolving both the price and exchange rate puzzles (C. Romer & D. Romer, 2004; Champagne & Sekkel, 2018; Ha et al., 2025). A recent study by Davlatov et al. (2026) applied a mixture of short- and long-run restrictions and resolved the price and exchange rate puzzles.

Following Uhlig (2005), the second scheme restricts the signs of the impulse responses. To our knowledge, this technique had not previously been brought to bear on Uzbek data, although it is well established in cross-country work (Mishra & Montiel, 2013). Scenario 1 removed the price anomaly, with the exchange rate direction imposed by construction, while Scenario 2 removed the exchange rate anomaly, with the price direction imposed; in the former, the weak and imprecisely estimated price response indicates that the pass-through is incomplete and still maturing. Earlier IMF analyses trace this incompleteness to structural features of the economy such as directed lending under government programs, the rates on which are set administratively and barely respond to policy, and a banking sector concentrated in a few state-owned institutions, where weak competition dampens the propagation of policy impulses (Poghosyan et al., 2023). Our results qualify that reading only in part: the exchange rate does move significantly once it is left unrestricted under Scenario 2, but the price response, while correctly signed under Scenario 1, remains statistically insignificant, so structural constraints on the price channel cannot be ruled out.

Next, IRFs results relying on the theory-based zero contemporaneous restrictions effectively addressed both the price and the exchange rate puzzles. Importantly, both are statistically significant as well as confirmed the last hypothesis of the study which the theory-based zero contemporaneous restrictions can resolve both the price and the exchange rate puzzle. Kim and Roubini (2000) applied the theory-based zero contemporaneous restrictions in small open economies and solved the price, exchange rate, and liquidity puzzles. Similarly, Elbourne and de Haan (2006) used Kim and Roubini-style identification and

resolved the price puzzle in ten transitional economies. The zero contemporaneous results reported here corroborate our own earlier findings obtained under this scheme (Davlatov & Sági, 2026); the distinctive element of the present paper is the parallel test under agnostic sign restrictions, applied to Uzbek data for the first time, which extends the robustness check to an identification strategy that neither Kim and Roubini (2000) nor Elbourne and de Haan (2006) employed. Notably, Aslanidi (2007) solved the exchange rate puzzle following Kim and Roubini (2000) style of identification. However, the author did not report confidence intervals of IRFs. Therefore, the statistically significant effect cannot be interpreted. Taken together with our earlier papers, the evidence indicates that the price puzzle documented for Uzbekistan is largely an identification artefact rather than a structural feature of the economy, a conclusion that now rests on three independent identification strategies rather than one. The exchange rate puzzle is also absent under both the zero contemporaneous and sign-restriction schemes in the full sample, but, as detailed in the Methods section, the sign-restricted exchange rate response is considerably less robust than the price result once the sample is split around the 2017 and 2020 regime changes or the 2017 liberalization outlier is separately controlled for; the zero contemporaneous evidence on the exchange rate is not subject to this particular check and should therefore be read with the same caution. This asymmetry between a robust price-side finding and a more fragile exchange rate-side finding is itself part of what this reassessment contributes, and it counsels caution in generalizing the size of the exchange rate response to other transitional economies with inflation-targeting regimes, even where the qualitative absence of a price puzzle may travel more safely.

CONCLUSION

This study assessed whether the price and exchange rate anomalies previously reported for Uzbekistan's monetary policy transmission are artefacts of the identification scheme rather than features of the economy, by comparing a recursive baseline against agnostic sign-restricted and theory-based zero contemporaneous identifications on a common monthly dataset, with particular attention to the robustness of the results across lag orders, subsamples, and the treatment of the 2017 exchange-rate liberalization. The recursive baseline reproduced both anomalies, with prices rising and the exchange rate depreciating after a contractionary shock; the alternative schemes reversed both responses in the full sample. The absence of a price puzzle proved robust across every specification examined, including both post-break subsamples, in which it strengthens further. The exchange rate appreciation, by contrast, while not reversing sign at 12 months, was several times smaller in the subsamples than in the full sample and lost statistical significance once the residual from the September 2017 liberalization was separately accounted for. These results indicate that the price anomaly documented for Uzbekistan is largely an artefact of a restrictive identification choice, a conclusion we consider robust; the exchange rate anomaly is directionally consistent with the same interpretation but rests on less solid ground, and we do not find robust support for the claim that transmission operates predominantly through the exchange rate rather than the price channel. Because the sign-restricted results describe a set of admissible models rather than a single point estimate, and the sample spans a period of substantial institutional change, these conclusions should be read as evidence on the direction of transmission rather than as precise, time-invariant magnitudes.

AUTHOR CONTRIBUTIONS

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Formal analysis: Elyor Davlatov, Judit Sági.
Funding acquisition: Csaba Lentner.
Investigation: Elyor Davlatov, Csaba Lentner.

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Resources: Csaba Lentner.
Software: Elyor Davlatov.
Supervision: Csaba Lentner, Judit Sági.
Validation: Judit Sági.
Visualization: Csaba Lentner.
Writing – original draft: Elyor Davlatov.
Writing – reviewing & editing: Judit Sági.

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APPENDIX A

Table A1. Descriptive statistics and normality test results

Variable	IP	CPI	PR	LR	M	EXCH	WCP
Mean	10.0	4.4	12.5	19.3	10.4	8.7	4.5
Median	10.2	4.5	13.1	20.8	10.5	9.0	4.5
Maximum	11.6	5.1	18.2	25.7	11.5	9.5	5.1
Minimum	7.3	3.8	6.9	12.4	9.2	7.6	3.8
Std. Dev.	0.9	0.4	2.6	3.8	0.6	0.7	0.3
Skewness	–0.2	0.0	–0.3	–0.3	–0.2	–0.5	–0.1
Kurtosis	2.1	1.6	2.2	1.6	1.9	1.5	2.4
Jarque-Bera	6.8	12.2	6.3	14.0	8.7	21.2	3.1
Probability	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Sum	1503.7	669.1	1881.0	2910.0	1577.3	1319.0	681.6
Sum Sq. Dev.	124.0	25.9	1036.9	2198.7	61.2	71.6	10.6
Observations	151	151	151	151	151	151	151

Table A2. Stationarity test

Variable	ADF_t	ADF_p	ADF_lag	PP_t	PP_p	PP_bw	nobs	cval_1	cval_5	cval_10	rej5_ADF	rej5_PP	rho
IP	–3.75	0.03	2	–7.45	0.01	4	151	–4.01	–3.46	–3.16	1	1	0.56
CPI	–2.42	0.41	1	–0.85	0.96	4	151	–4.01	–3.46	–3.16	0	0	0.96
PR	–2.93	0.20	0	–2.66	0.31	4	151	–4.01	–3.46	–3.16	0	0	0.89
LR	–1.95	0.61	1	–1.98	0.59	4	151	–4.01	–3.46	–3.16	0	0	0.94
M	–3.69	0.03	0	–3.44	0.05	4	151	–4.01	–3.46	–3.16	1	0	0.84
EXCH	–0.70	0.97	0	–1.33	0.87	4	151	–4.01	–3.46	–3.16	0	0	0.99
WCP	–2.53	0.36	1	–1.53	0.78	4	151	–4.01	–3.46	–3.16	0	0	0.96

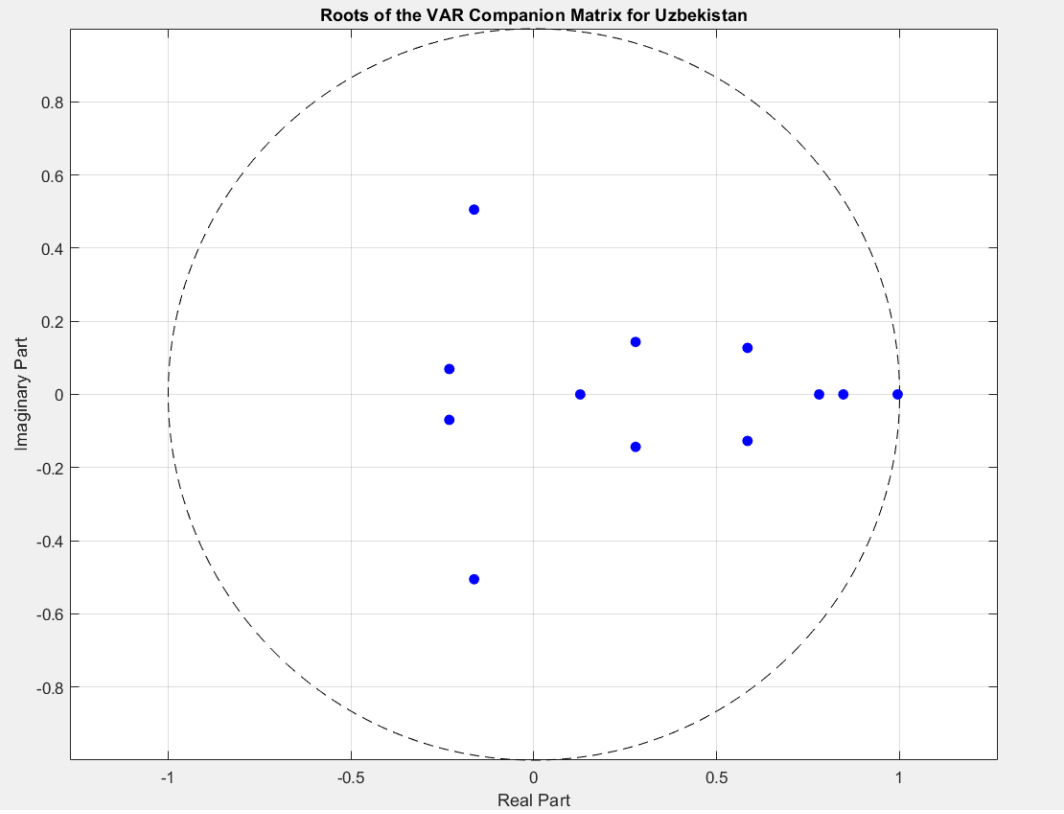


Figure A1. Stability test

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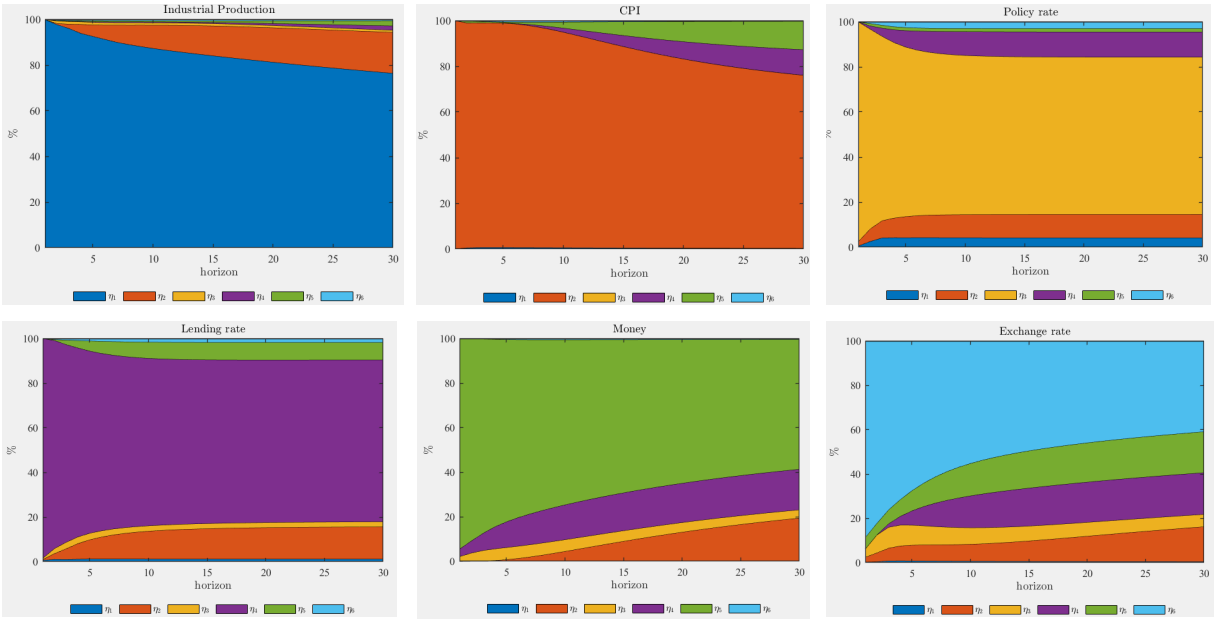


Figure A2. Forecast error variance decomposition

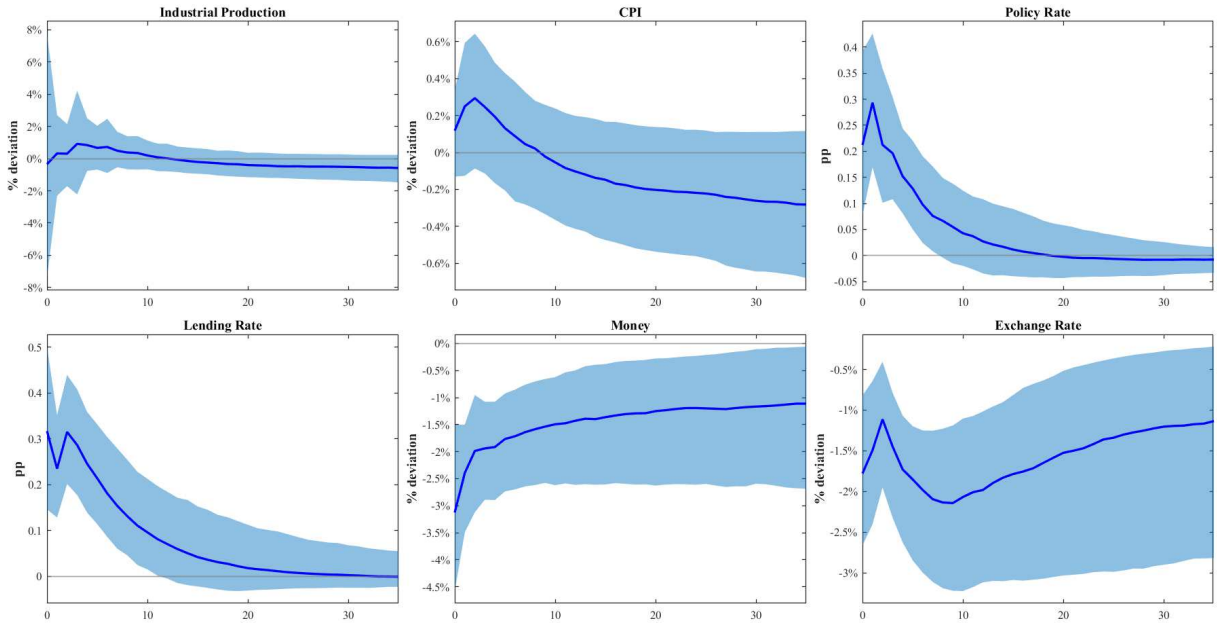


Figure A3. Robustness check of sign restrictions (scenario 1)

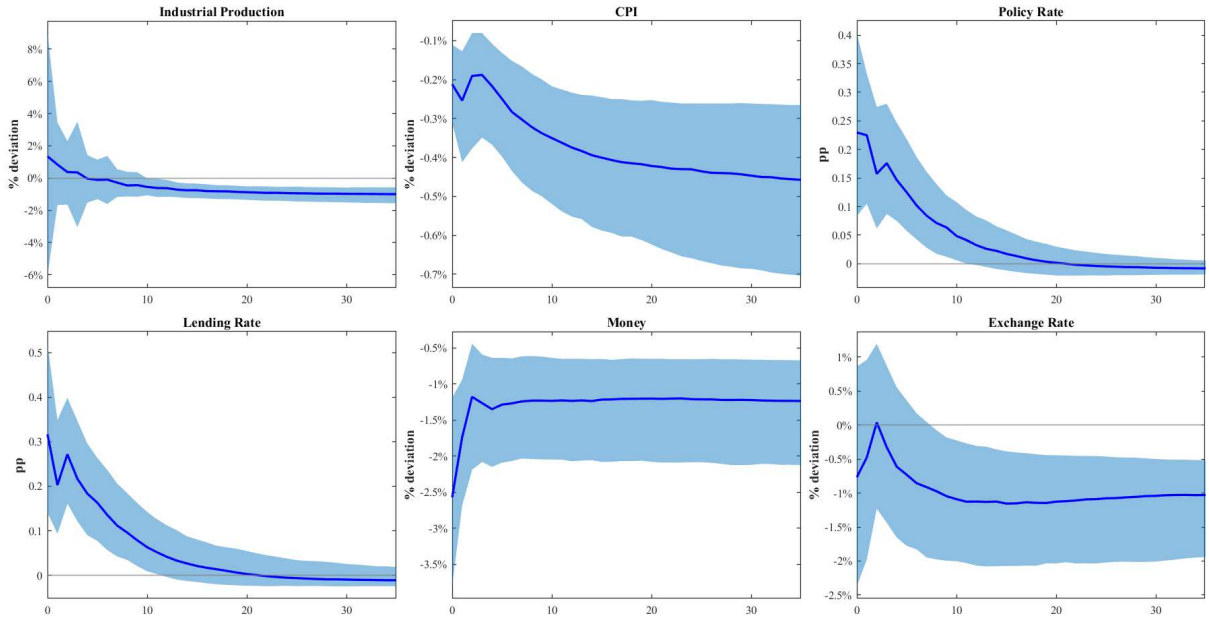


Figure A4. Robustness check of sign restrictions (scenario 2)

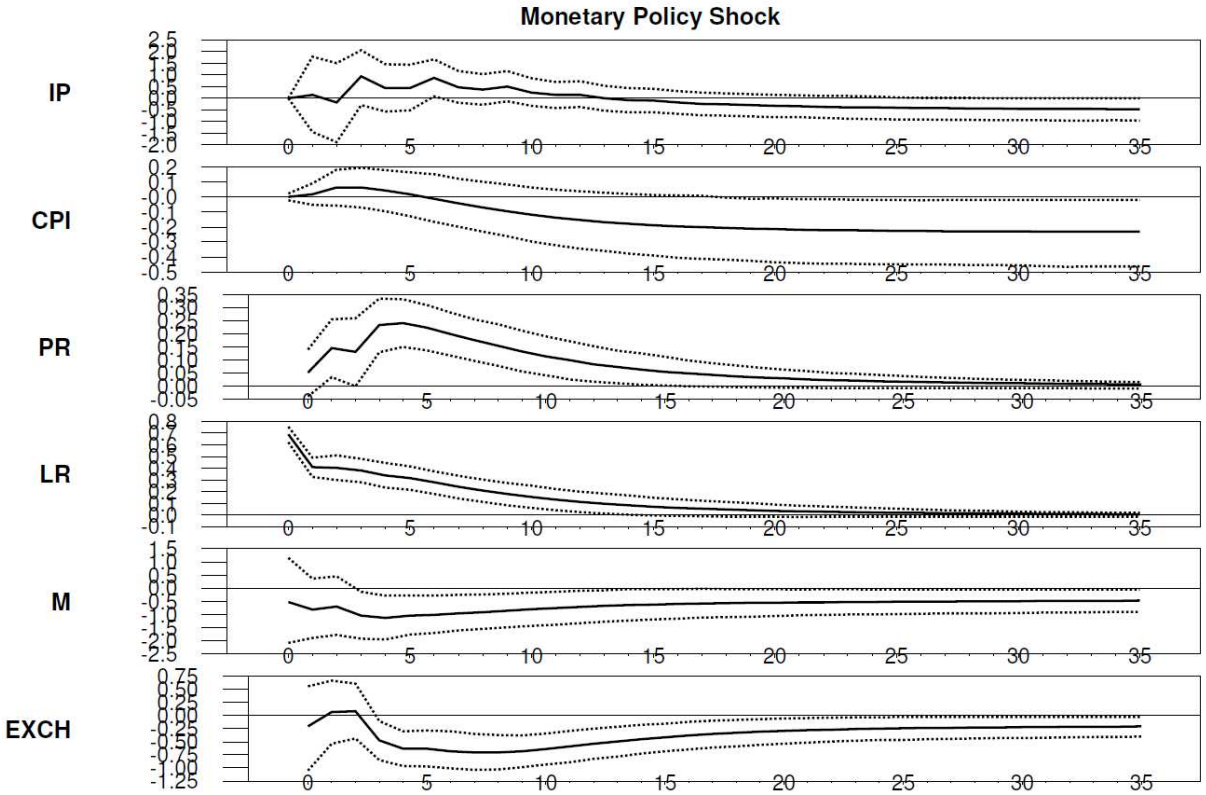


Figure A5. Robustness check of zero contemporaneous restrictions

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APPENDIX B. Structural stability tests (likelihood-ratio and Chow break-point tests)

Parameter stability of the reduced-form VAR(2) underlying Figures 2 and 3 is tested at the two regime changes covered by the sample: the exchange-market liberalization of September 2017 and the transition to inflation targeting in January 2020. The slope-stability likelihood-ratio (LR) test augments the VAR with interactions between the post-break dummy and all lagged endogenous variables and the world commodity price index (78 additional coefficients), keeping both step dummies; it includes a small-sample degrees-of-freedom correction, and its p-values are obtained from 1,999 wild-bootstrap replications, which remain valid if the volatility of shocks differs between regimes. The Chow break-point test examines the joint constancy of the coefficients and the residual covariance matrix; because asymptotic Chow tests are oversized in samples of this size, its p-values are obtained from 1,999 residual-bootstrap replications. The third test compares the residual covariance matrices before and after the break.

Table B1. Stability tests for the reduced-form VAR(2), 2013M03–2025M07 (T = 149)

Test	Null hypothesis	Break at 2017M09	Break at 2020M01
Slope stability (LR)	Lag and WCP coefficients constant	LR = 340.2 (df = 78) p < 0.001	LR = 237.9 (df = 78) p = 0.001
Chow break-point test	Coefficients and residual covariance constant	BP = 706.9 (df = 111) p < 0.001	BP = 585.1 (df = 105) p < 0.001
Equal residual covariance (LR)	Residual covariance matrix constant	LR = 205.1 (df = 21) p < 0.001	LR = 177.0 (df = 21) p < 0.001

Note: Bootstrap p-values (1,999 replications; smallest attainable value 0.0005) for the first two tests and asymptotic $\chi 2$ p-values for the third. For the slope-stability test at 2017M09, the 95th and 99th percentiles of the bootstrap distribution are about 160 and 187.

Table B2. Robustness of the stability tests to the specification

Specification	Slope LR 2017M09	Slope LR 2020M01	Chow BP 2017M09	Chow BP 2020M01
VAR(2), as in Figures 2-3 (baseline)	340.2 (78)	237.9 (78)	706.9 (111)	585.1 (105)
	p < 0.001	p = 0.001	p < 0.001	p < 0.001
VAR(3)	311.4 (114)	256.4 (114)	737.2 (147)	639.4 (141)
	p < 0.001	p < 0.001	p < 0.001	p < 0.001
VAR(2) with intercept	277.2 (78)	198.7 (78)	642.0 (111)	528.5 (105)
	p < 0.001	p < 0.001	p < 0.001	p < 0.001
VAR(2) with 2017M09 impulse dummy	131.7 (78)	125.1 (78)	381.8 (117)	342.0 (105)
	p = 0.003	p = 0.02	p < 0.001	p < 0.001

Note: Test statistics with degrees of freedom in parentheses; bootstrap p-values (1,999 replications). When the one-off devaluation of September 2017 is captured by an impulse dummy, the slope-stability test still rejects at both dates.

Parameter constancy is rejected at both dates. The structural dummies capture shifts in levels but not changes in the dynamics of the system, so the full-sample estimates should be read as averages over policy regimes. Because these tests concern all six equations of the reduced-form VAR jointly, the sign-restricted responses are re-estimated on the post-break subsamples in Appendix C.

APPENDIX C. Sign-restricted results for the subsamples 2017M09–2025M07 and 2020M01–2025M07

The sign-restricted model is re-estimated on the post-liberalization subsample (2017M09–2025M07, T = 93; intercept, WCP and the 2020 step dummy) and on the post-transition subsample (2020M01–2025M07, T = 65; intercept and WCP). The restrictions (Table 3, imposed at h = 0-5), the number of accepted draws (500) and the 68% bands are the same as for the full sample, and two lags are kept for comparability. Both subsample VARs are stable (largest roots 0.994 and 0.992).

Table C1. Informative responses across samples (one-standard-deviation shock, VAR(2))

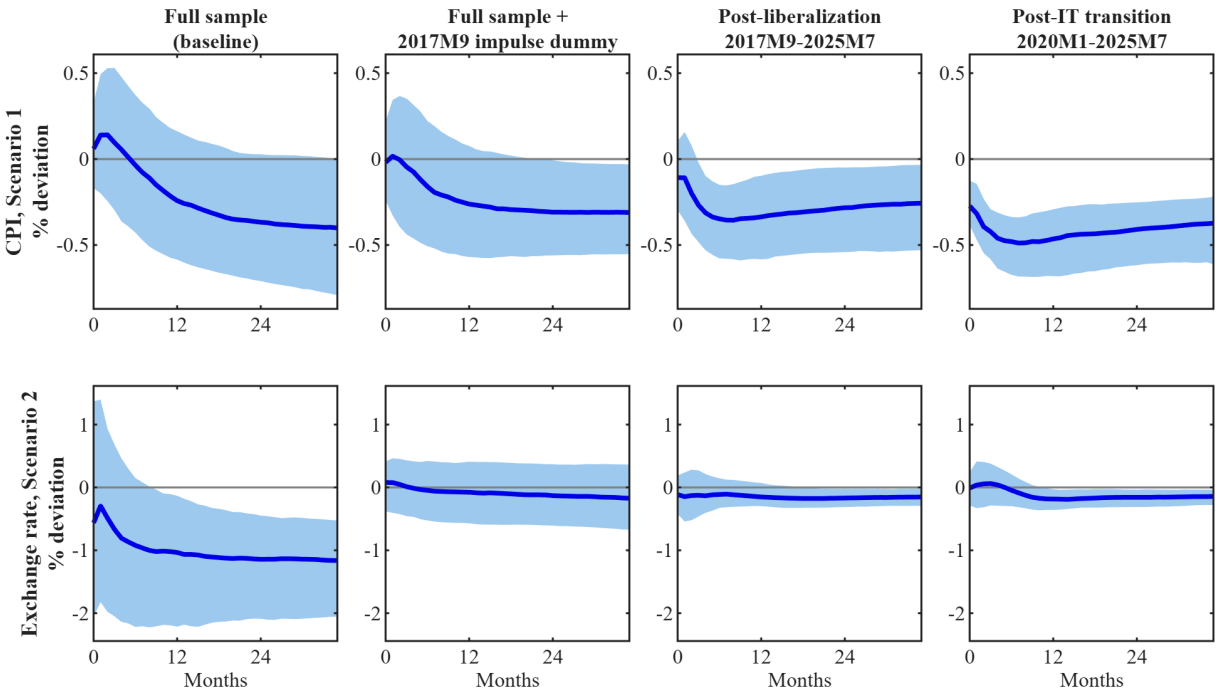
Sample	Policy-rate impact, pp (Sc. 1 / Sc. 2)	CPI, Scenario 1: month 12, median [68% band]	CPI: share of draws with a decline; months with band below zero	EXCH, Scenario 2: month 12, median [68% band]	EXCH: share of draws with an appreciation; months with band below zero
Full sample 2013M01–2025M07 (T = 149)	0.26 / 0.23	−0.24	0.71	−1.03	0.88
		[−0.59; 0.16]	none	[−2.21; −0.13]	9-35
Post-liberalization 2017M09–2025M07 (T = 93)	0.19 / 0.18	−0.34	0.90	−0.15	0.78
		[−0.58; −0.10]	3-35	[−0.30; 0.07]	19-35
Post-transition 2020M01–2025M07 (T = 65)	0.13 / 0.13	−0.47	1.00	−0.18	0.87
		[−0.68; −0.29]	0-35	[−0.36; −0.03]	11-35

Note: Responses in percent. Months refer to h = 0-35. A negative exchange rate response is an appreciation of the sum. No sample shows a significant CPI increase (Scenario 1) or a significant depreciation (Scenario 2) at any horizon.

Table C2. Degrees of freedom and performance of the sign-restriction search by sample

Variable	Full sample	Post-liberalization	Post-transition
Monthly observations per equation (T)	149	93	65
Regressors per equation (k) / coefficients in the VAR	15 / 90	15 / 90	14 / 84
Observations per regressor (T / k)	9.9	6.2	4.6
Residual degrees of freedom per equation (T − k)	134	78	51
Acceptance rate of candidate rotations (Sc. 1 / Sc. 2)	43.6% / 21.7%	6.7% / 8.2%	0.2% / 0.4%
Posterior draws discarded, no admissible rotation (Sc. 1 / Sc. 2)	0 / 0	2 / 2	340 / 183
VAR(3): regressors per equation; feasibility	21; feasible (Figures A3 and A4 Appendix A)	21; feasible, acceptance 1.2% / 1.5%	20 for 64 observations; rotation search not completed

Note: Acceptance rate = 500 accepted draws divided by the number of candidate rotations tried.



Note: Solid lines: pointwise posterior medians; shaded areas: 68% bands (500 accepted draws). Identical sign restrictions (Table 3, h = 0-5) and VAR(2) in all panels; common vertical scale within each row. The second column adds an impulse dummy for 2017M09 to the full-sample model.

Figure C1. CPI response in Scenario 1 (top) and exchange rate response in Scenario 2 (bottom) across samples

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In both subsamples the price level falls significantly when it is left unrestricted (Scenario 1), and the currency appreciates when the exchange rate is left unrestricted (Scenario 2). The appreciation at 12 months is, however, considerably smaller than in the full sample (0.15-0.18% against 1.03%) and significant only from month 19 and month 11, respectively. With one lag, the CPI response at 12 months in Scenario 1 is −0.40% in both subsamples and significant, while the exchange rate response in Scenario 2 is −0.21% (post-liberalization) and −0.14% (post-transition) and not significant. Because the subsample VARs estimate 14-15 coefficients per equation from only 65-93 observations (Table C2), these estimates are interpreted as evidence on the direction rather than the magnitude of the responses.