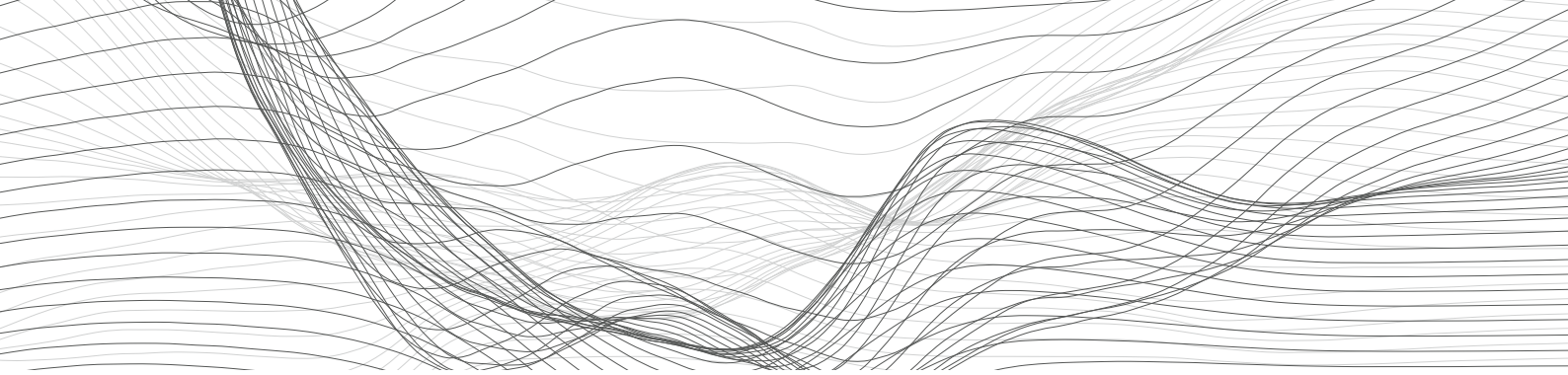

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Money, Inflation and the Financial Crisis: The Case of Switzerland*

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Abstract

Unconventional monetary policies have sometimes raised inflation-related fears that have not materialized. Switzerland presents an interesting case, as the central bank reacted to an appreciating currency by injecting Swiss francs through foreign exchange interventions, and bank lending increased considerably throughout the financial crisis. The low inflation that occurred after the crisis can be reconciled with the substantial money growth during the crisis by accounting for the effects of the lower equilibrium velocity and portfolio shifts associated with the Swiss National Bank's foreign exchange interventions.

JEL classification: E52; E58; E41; E30

Keywords: Monetary policy; Monetary aggregates; Inflation; Equilibrium velocity; Foreign exchange interventions

*The views expressed in this paper do not necessarily reflect those of the Swiss National Bank. We are grateful to Petra Gerlach, an anonymous referee, as well as the SSES 2019 annual congress and SNB seminar participants for their helpful discussion and comments.

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1 Introduction

The dramatic increase in the reserves that commercial banks have at central banks, which is a result of the unconventional monetary policies employed in response to the recent financial crisis, has sometimes raised inflation fears that have not materialized. The economic and monetary developments that occurred in Switzerland during the crisis are particularly interesting. Because the crisis originated externally, bank lending was strong throughout the crisis and the central bank reacted to an appreciating currency by injecting Swiss francs (CHF) through foreign exchange (FX) interventions. A considerable amount of bank lending and FX interventions have lead to a considerable increase in broad monetary aggregates, with growth rates of approximately 10 percent; however, inflation has remained low.

This paper extends the analysis of Reynard (2007) to include the effects of the financial crisis. Reynard's paper derived a monetary policy stance measure based on monetary aggregates that can be used as an indicator enabling avoidance of a persistent increase in inflation above the monetary policy objective. Through an analysis of the Swiss case, this paper shows that the relationship between broad money and inflation that Reynard found in the cases of U.S., Euro Area and Switzerland between the 1960s or 1970s and 2006 was not affected by the financial crisis. The lower equilibrium velocity as well as the portfolio shifts associated with the Swiss National Bank's (SNB) FX interventions imply a low level of excess liquidity despite the high money growth.[1] This is consistent with a low-inflation environment.

[1] As explained below, excess liquidity is defined in this paper as broad money (M2) deviations from long-term equilibrium.

The relationship between money and inflation before the 1960s has, of course, been well documented by Friedman and Schwartz (1963). Nelson (2003) reviews the monetarist literature, relates it to the modern New Keynesian dynamic stochastic general equilibrium (DSGE) models used for monetary policy analysis, and concludes that the information content of money found in empirical studies comes from its ability to proxy for various asset yields and their effects on aggregate demand.[2]

The analysis of this paper is based on the P* approach developed by Hallman, Porter and Small (1991), which relates inflation to deviations from a long-term money demand equation. The basic idea of this approach is that when the money level is greater than the level that is required for the economy to sustain long-term values of output and velocity, this should lead to upward pressures on inflation. The historical roots of P* analyses can be found in Humphrey (1989), with the statistical tests dating back to the study of Working (1923). More recent applications of this framework from different perspectives can be found in Orphanides and Porter (2000) and Belongia and Ireland (2015).

The econometric relationship between monetary aggregates and inflation has also been well documented in the cases of the Euro Area and Switzerland by various studies. For example, Gerlach and Svensson (2003) find support for a P* model in the context of the Euro Area, and related measures of excess liquidity are used to analyze monetary developments in Masuch, Pill

[2]For recent developments on including the financial sector and different yields in DSGE models, see, e.g., Adrian and Shin (2009), Brunnermeier and Sannikov (2014), or Coenen, Karadi, Schmidt and Warne (2018). However, bank deposits are not included in the empirical analysis of these papers.

and Willeke (2001) and Dreger and Wolters (2014).

The usefulness of money in explaining Swiss inflation is analyzed, for example, in Jordan, Peytrignet and Rich (2001) and in Gerlach-Kristen (2007), who assesses the effects of trend money growth and output gaps on inflation and includes an extended literature review on the impact of money and of real economic activity on inflation in Switzerland.

Our econometric results on the effects of monetary shocks on economic activity are consistent with the narrative account of Friedman (1968) and the benchmark estimated effects of monetary policy shocks documented in Christiano, Eichenbaum and Evans (2005). We follow the latter paper's approach of characterizing the effects of monetary policy shocks in terms of vector autoregression (VAR) impulse responses and variance decompositions.

As this paper focuses on the Swiss monetary developments since the recent financial crisis, it begins in Section 2 with a discussion of the evolution of the central bank and of broad money during the crisis in relation to the SNB's FX interventions. Section 3 analyzes money demand and the effect of the considerable decline in nominal interest rates since the 1990s. Then, Section 4 presents the evolution of the excess liquidity monetary policy stance measure and its relationship with the subsequent business cycles and inflation developments since the end of the Bretton Woods system in the mid-1970s.

The econometric properties of the excess liquidity measure are analyzed in detail in Section 5. Excess liquidity shocks lead to output gap and inflation exhibiting hump-shaped responses, which are delayed and longer-lasting

for inflation. Using a historical decomposition of the past 40 years, we characterize the effects of the three most important shocks, namely, excess liquidity, cost-push and real exchange rate shocks, on inflation developments. Finally, Section 6 concludes.

2 Central bank and broad money

The direct counterparts of central banks' open market operations are commercial banks. During normal times, i.e., before the financial crisis, central banks injected reserves into the interbank market to decrease short-term interest rates by buying bonds from or conducting repo operations with commercial banks. This directly increased narrow money or M0 (i.e., banknotes and domestic commercial banks' reserves at the central bank) and lowered commercial banks' refinancing costs.

This phenomenon led banks to increase the amount of loans that they grant to their customers; as a result, broad money (e.g., M2, composed of cash and customers' sight and savings deposits at commercial banks) increased. Broad money, i.e., money held by the non-banking domestic private sector, is the relevant money measure to be used as an indicator for future inflation, as it represents the means that is used to pay for goods and services transactions. The sight deposits (i.e., reserves) of domestic banks at the SNB are not part of M1, M2 or M3 monetary aggregates (i.e., broad money).

Due to quantitative easing (QE), M0 has also directly increased by the amount of assets purchased by central banks, as commercial banks are al-

ways the direct counterparts of central banks. However, the interbank market has been satiated; thus, reserve variations no longer have an effect on banks' lending. However, broad money also directly increased when the asset sellers were from the non-banking domestic private sector.[3]

Indeed, broad monetary aggregates consist of coins, banknotes and residents' deposits both at domestic bank offices and at their branches abroad. When the central bank buys assets from a resident, it credits the sight deposit (i.e., reserves held at the central bank) of the commercial bank in which that resident holds an account; thus, both M0 and broad money increase, as the commercial bank credits its customer's deposit.

In the Swiss case, some of the counterparts of the SNB FX interventions were nonbanking domestic private residents. As these residents sold their foreign currency to the SNB and received CHF deposits, broad money increased. This particular increase in broad money represents portfolio substitutions and should not lead to inflationary pressures, in contrast to broad money increases due to commercial banks' lending. In contrast to bank lending which accommodates credit demand for consumption purposes, funds allocated to foreign currency investments were not meant to be used for consumption purposes related to Swiss goods and services. As seen in Figure 1, broad money increased relatively faster than loans between 2008 and 2013, as the SNB intervened in the FX market during this time.

To assess the relationship between money and inflation, we will deduct from broad money levels the cumulative difference between the increase in

[3]In the US, for example, "households" (which include hedge funds) were the counterparts for about half of QE by 2015, as described in Carpenter et al. (2015).

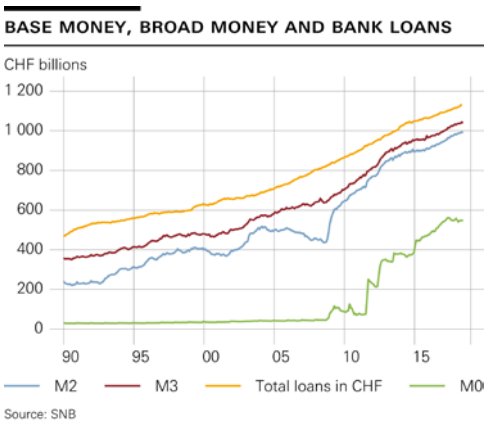

FIG. 1. Money and Loans

M3 and the increase in loans between 2008 and 2013. The adjustment remains constant after 2013. M3 is used instead of M2 for this adjustment, as the difference between loans and M3 reflects the SNB interventions. For a given money creation through credit, which increases both loans and M3 together, people transfer funds in and out of their transaction accounts (included in M2 and M3) from and to term deposits (included in M3 but not M2) as the interest rate fluctuates. Below we show the effect of this adjustment on the excess liquidity measure that we use. At its peak in 2013, this adjustment amounts to approximately CHF 100 billion, or 5 percent of the excess liquidity.

3 Money demand and equilibrium velocity

In this section, we assess and estimate Swiss money demand. The estimated coefficients of this money demand will then be used to compute excess liquidity in Section 4.

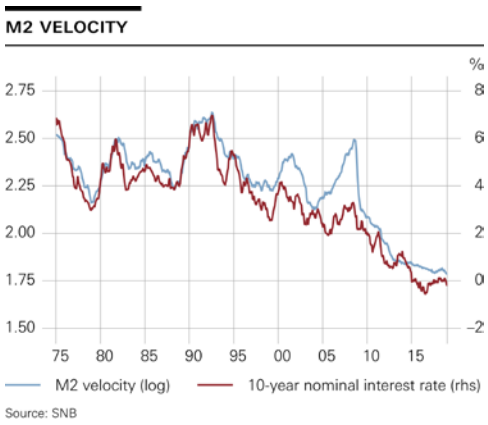

FIG. 2. Money Velocity

3.1 Money and interest rates

Figure 2 displays the velocity of M2 and the 10-year nominal interest rate. The velocity of money is defined as the nominal GDP divided by the money level. The money level M2 is defined as coins, banknotes, transaction and saving deposits. The conceptual and empirical considerations behind the choice of the specific monetary aggregate M2 will be presented in Section 4.1.

As is apparent from this graph and econometrically tested below, money demand has been stable over the past 4 decades, and there are no shifts due to the financial crisis. A prominent feature of this graph is the velocity decline since the 1990s. The sharp decline in interest rates since the early 1990s is due to both a decline in inflation and a decline in real interest rates. As discussed in Section 4, changes in equilibrium velocity, whether due to changes in inflation or in real interest rates, have important implications for monetary analysis and must be accounted for.

3.2 Money demand econometric estimates

The estimated money demand equation includes corrected M2 (m_t), the CPI (p_t), real GDP (y_t) and the long-term nominal interest rate (i_t) over the period 1975-2018 and can be expressed[4] as

$$m_t - p_t - y_t = b_0 + b_1 i_t + \varepsilon_t.$$

The unit root tests indicate that the series are I(1), and we use two cointegration regression methods, namely fully modified OLS and dynamic OLS. In the case of the latter method, the lag and lead length were selected according to AIC. The corresponding results are reported in Table 1. Two aspects of these results are noteworthy. First, the null hypothesis of no cointegration can be clearly rejected at the 5% level. Second, both methods lead to nearly identical results with high statistical significance and R-squared values and indicate an interest rate semi-elasticity of approximately -0.095.

Method	b_0	b_1	R^2	DW	Cointegration Test
FMOLS	-3.044***	-0.0949***	0.8592	0.2402	-3.755**
	(0.0213)	(0.00559)			Phillips-Ouliaris
DOLS	-3.052***	-0.0930***	0.8592	0.2402	-3.658**
	(0.0170)	(0.00559)			Engle-Granger

Newey-West standard errors in parentheses.
*, **, *** indicates significance at the 10, 5 and 1% level, respectively.

Table 1: Estimates of M2 Demand Function (1975Q1 - 2018Q3)

[4]We follow Lucas (1988) and estimate money demand in its simplest theoretical form with unitary income elasticity. We have also estimated an unrestricted money demand function in which the coefficients of income and price levels are not restricted to unity. The no-cointegration hypothesis is clearly rejected, and the coefficients of Y and CPI are statistically insignificantly different from unity. Moreover, the hypothesis that these two coefficients are equal cannot be rejected.

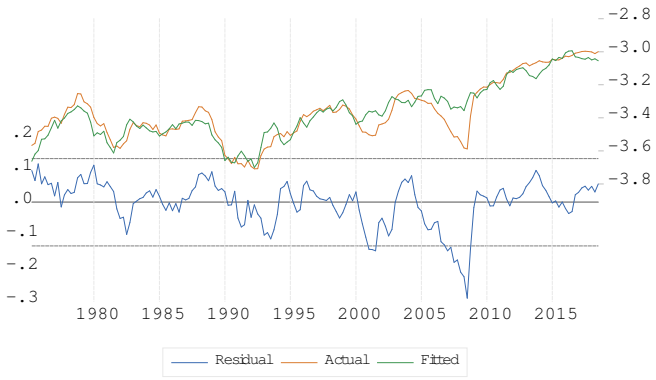

FIG. 3. Fit of FMOLS Regression for M2 Demand

Figure 3 shows the actual and fitted values as well as the residuals of the FMOLS regression, illustrating that these residuals have a good fit and a stationary appearance. Moreover, we re-estimated the equation using OLS and tested sequentially for multiple breaks according to the method of Bai and Perron. The OLS parameter estimates and the statistical properties of this analysis are essentially the same as those reported in Table 1, and we find no break in the regression coefficients at the 5% significance level. All these findings suggest that our money demand estimates are very reliable and stable.

4 Money, business cycle and inflation developments

4.1 A measure of excess liquidity

This section presents a measure of excess liquidity constructed for the purpose of providing a signal of future substantial and persistent inflation fluc-

tuations, i.e., changes in inflation environments, and analyzes the evolution of the excess liquidity, output gap and inflation in Switzerland since the mid-1970s. It extends the empirical analysis of Reynard (2007) to include the effects of the financial crisis in the case of Switzerland.

The usefulness of money as an early indicator of major inflation and business cycle fluctuations is confirmed. At least since the 1970s, episodes of substantial excess liquidity in the U.S., the Euro Area and Switzerland have always been followed by substantial and persistent increases in inflation, and major increases in inflation have always been preceded by substantial excess liquidity. The situation is no different in the case of the financial crisis. When correctly measured, it can be observed that excess liquidity has remained low since the crisis and has been followed by low inflation.

A minimal structure is imposed on the data in the form of long-term adjustments based on the quantity theory of money. In this way, deviations from long-term equilibrium, or excess liquidity, provide useful signals of subsequent business cycle booms and busts and of subsequent and persistent changes in the inflation environment.

This framework is based on the P* concept presented by Hallman, Porter and Small (1991) and accounts for changes in the equilibrium velocity. Reynard (2007) shows that accounting for the decrease in equilibrium velocity since the 1990s is not only important for uncovering a relationship between money and inflation that is useful for monetary policy, but omitting the velocity adjustment biases econometric estimates.

The financial crisis has made two specific adjustments to the monetary series necessary: the decline in the equilibrium velocity, discussed in Section

3, that started in the early 1990s needs to be applied to the full sample; and the effects of the SNB's FX interventions, discussed in Section 2, need to be accounted for.

Consistent with the analysis of Reynard (2007), the monetary variable (m^*) considered is defined as

$$m_t^* \equiv c + m_t - y_t^* + \beta i_t^*, \tag{1}$$

where c is a normalization constant estimated from the money demand equation provided in Section 3, m is the observed broad money level M2, y^* is the real potential output derived from a production function, β is the estimated interest rate semi-elasticity of the real money demand equation provided in Section 3 in which a unitary income elasticity is imposed, and i^* is a low-frequency HP-filtered long-term nominal interest rate. All the variables except interest rates are in logarithms.

Money represents a broad monetary aggregate and is defined as M2 in the empirical analysis. It includes cash and zero-maturity deposits that can be used directly (e.g., cash or transaction deposits via credit card) or indirectly (via immediate transfers at par and no cost, such as transfers from savings accounts) to buy goods and services.

We use M2 instead of M1 because funds in savings accounts (which are included in M2 but not in M1) can mostly be transferred on demand and without penalty. The upper limit on these transfers, which is typically CHF 50,000 yearly without a 3-month advance notice, is relatively high. Thus, these accounts are close substitutes for customer sight deposits, and their

yields are similar to those of sight deposits, i.e., they are lower than money market rates and move only if there are persistent changes in the policy interest rate.

M2 is chosen instead of M3 because the assets included in M2 are closer to the transaction concept of money; thus, they are empirically more likely to exhibit a stable and close relationship with inflation and economic activity. Our consideration of M3 in the empirical analysis confirms this. M3 includes time deposits with maturities up to several years, and early withdrawals from these assets are subject to a penalty. Thus, the relationship between M3 and purchases of goods and services is weaker. Moreover, time deposits offer yields at or above policy interest rates. The amounts of these assets thus decrease with a decline in policy rates, and vice versa, thus offsetting the useful monetary policy stance signal of monetary aggregate fluctuations.

Money differs from bonds (and from other assets) in that it is the only means of payment. Bonds can be sold relatively quickly in exchange for money, either directly or via a repurchase agreement, but it is costly to do so. As a consequence, people hold a total of CHF 1 trillion in M2 money that earns very little interest, i.e., less than the interest paid on short-term government bonds; this was the case even before the financial crisis. Moreover, when money is exchanged within the nonbanking sector via transactions involving goods or services or is exchanged against debt, the means of transaction is transferred from one economic agent to another; thus, aggregate consumption cannot increase. Only when banks or the central bank create money can aggregate consumption increase (for a given velocity of money that is closely related to interest rates).

In the following analysis, we use the interest rate semi-elasticity β of 0.095 estimated in Section 3. This is robust to different specifications and sample choices. As explained in Section 2, the cumulative difference between the increase in M3 and the increase in CHF loans between 2008 and 2013 is removed to account for the SNB's FX interventions, and this adjustment remains constant thereafter. By 2013, this adjustment amounts to approximately CHF 100 billion.

The definition of m^* is equivalent to that of the variable labeled p^* in the P* concept, except that Hallman et al assumed that velocity was constant. Using equation (1), the difference between m_t^* and p_t can be expressed as $m_t^* - p_t = m_t - \widehat{m}_t$, where $\widehat{m}_t$ is the money that would be demanded at the equilibrium output and interest rates given the current price level, i.e., $\widehat{m}_t = -c + p_t + y_t^* - \beta i_t^*$. The difference between m_t^* and p_t represents a measure of excess liquidity, i.e., money in excess of a long-run equilibrium money demand.

Excess liquidity is thus the proportion of observed M2 in excess of the amount that would be demanded if output was at its potential level and money velocity was at its equilibrium point. When commercial banks create broad money in excess of the amount needed when production is at its potential, the adjustment has historically been done by increasing inflation, as bank loans rarely decrease. Excess liquidity depends not only on monetary policy but also on monetary policy transmission, i.e., on commercial banks' lending behavior as well as on consumer and firm demand for loans.

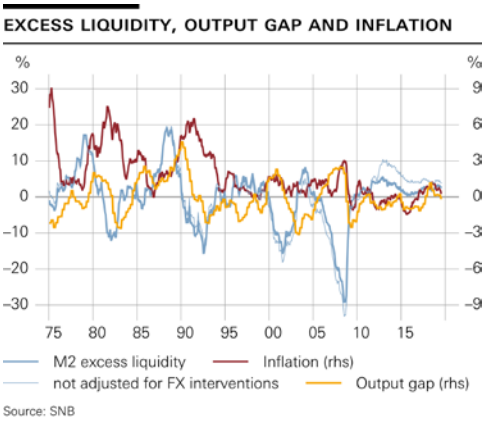

FIG. 4. Excess Liquidity and Economic Activity

4.2 Excess liquidity and economic activity

Figure 4 displays the relationship between excess liquidity, defined as $m_t^* - p_t$, inflation and the output gap in Switzerland since the mid-1970s. This figure also shows the excess liquidity series unadjusted for the FX interventions. The largest difference occurred in 2013, when the non-adjusted excess liquidity was approximately 5 percent greater than the adjusted measure.[5]

There have been two episodes of high excess liquidity of approximately 15-20 percent during the late 1970s and late 1980s; during these episodes, expansionary monetary policies and bank lending were followed, after a few years, by a booming economy and substantial, persistent increases in inflation reaching over 6 percent during the early 1980s and early 1990s. The response of output and especially of inflation to high excess liquidity is delayed and can take up to 5 years; these phenomena are also featured in the

[5]The small differences occurring before 2008 are due to slight differences in the estimated coefficients for money demand, which are used to compute the excess liquidity measures, depending on whether FX adjusted or non-adjusted monetary aggregates are considered.

econometric properties of excess liquidity discussed in Section 5.

The positive excess liquidity episodes of 1996–1998 and 2003–2004 were also followed by positive output gaps and increasing inflation. However, because excess liquidity had remained relatively low since the 1990s, inflation remained low as well. When excess liquidity was negative, the output gap subsequently became negative and inflation decreased; however, inflation rarely became negative, reflecting downward nominal rigidities.[6] These major monetary expansion and tightness episodes correspond to the findings of the analysis of Baltensperger and Kugler (2017), who examine Swiss monetary history since the early 19th century.[7]

Consistent with earlier findings, we find that episodes of substantial excess liquidity have been followed by substantial and persistent increases in inflation, and major increases in inflation have been preceded by substantial excess liquidity. During the past decade, the level of excess liquidity has remained low and particularly stable, which is consistent with a low-inflation environment.

The early ability of excess liquidity to indicate inflation is clearly seen in Figure 5, which displays yearly excess liquidity with a 2-year lag and the output gap. Figure 6 displays 3-year lagged excess liquidity and inflation. It takes an additional year after excess liquidity has affected the output gap to observe a rise in inflation. This lag has lengthened even more since the late 1990s.

[6] The sharp decrease in excess liquidity from 2006-2007 was due to the abnormally large decrease in money demand following the increase in interest rates during that period, as shown in Figure 2.

[7] See, for example, p.160.

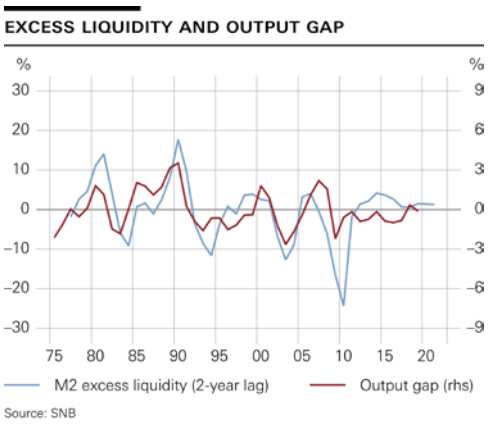

FIG. 5. Lagged Excess Liquidity and Output Gap

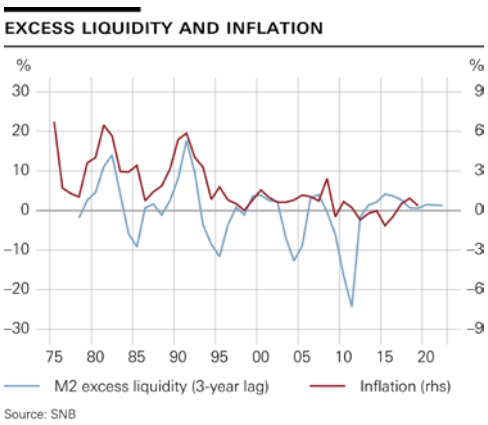

FIG. 6. Lagged Excess Liquidity and Inflation

5 Econometric properties of excess liquidity

5.1 Model specifications

In this section, we provide structural VAR estimates of the dynamic effects of shocks in M2 excess liquidity (M2CEXCESSLIQUIDITY) on the output gap (YG), inflation (INFPY), the 10-year nominal interest rate (IL) and the real effective exchange rate (LREER). The latter variable is introduced to control for movements in the exchange rates, which are very important for the highly open Swiss economy. These data are displayed in Figure 7.

Table 2 shows the unit root and stationarity tests. For LREER, INFPY and YG, the results support the stationarity assumption. For IL, the tests indicate non-stationarity. However, this might be the result of a historically limited sample with extraordinary interest rate fluctuations. According to Sims, Stock and Watson (1990), VAR estimates remain consistent in the cases of some unit roots, and the coefficient estimates of stationary right-hand variables have standard asymptotic distributions. Thus, the Granger causality tests shown below would be valid with a non-stationary IL, except in the cases of the tests involving the influence of IL on the other variables. Moreover, we can expect that the confidence interval of the impulse responses will only be mildly distorted, as we only have a few IL coefficients involved in the calculations.

We set a lag length of two, which is optimal according to the Hannan-Quinn information criterion. Table 3 shows the test results of the lagged interactions of the five variables ("Granger causality" test) using 169 observations (1975Q1-2018Q4). The table reports a chi-squared statistic for

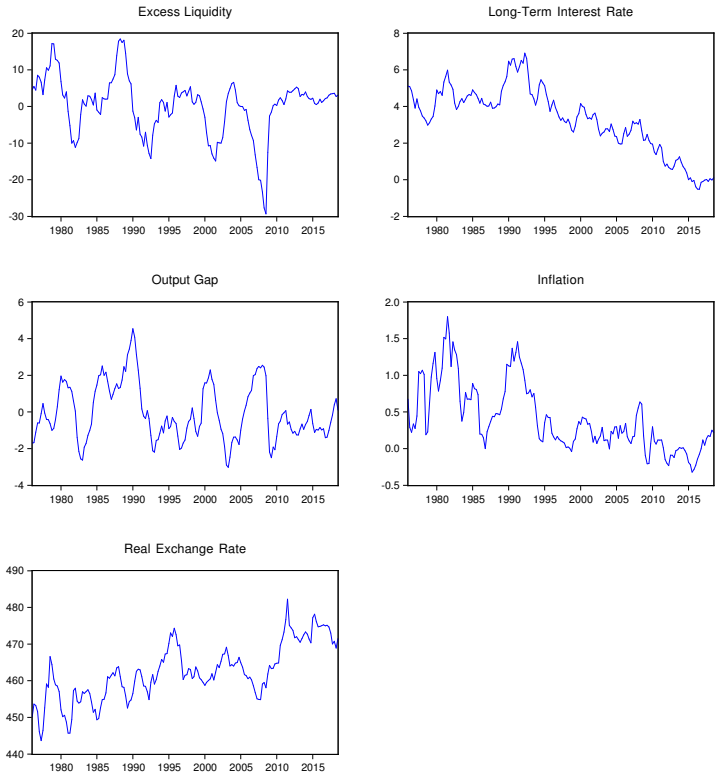

FIG. 7. Excess Liquidity, Long Term Interest Rate, Output Gap, Inflation and the Real Exchange Rate, 1976-2018

	ADF	PP	KPSS
LREER	-4.281***	-3.731**	0.0768
IL		-2.343	0.2881***
INFPY		-3.404*	0.0517
YG		-3.673**	0.0576
Kwiatowski-Philips-Schmidt-Shin test statistic			
Asymptotic critical values:		1% level (***)	0.216000
		5% level (**)	0.146000
		10% level (*)	0.119000

Table 2: Unit Root and Stationarity Tests (1975 - 2018, including deterministic trend)

each of the other four variables (with two degrees of freedom) as well as for all of the variables jointly (with 8 degrees of freedom), and it reports each corresponding marginal significance level.

Dependent variable: Excess Liquidity	Chi-sq	Prob.
Excluded		
Interest Rate	13.00458	0.0015
Output Gap	7.551075	0.0229
Inflation	1.050968	0.5913
LREER	1.694920	0.4285
All	29.58811	0.0002
Dependent variable: Interest Rate	Chi-sq	Prob.
Excluded		
Excess Liquidity	18.82805	0.0001
Output Gap	8.618731	0.0134
Inflation	3.701451	0.1571
LREER	3.624273	0.1633
All	31.52299	0.0001
Dependent variable: Output Gap	Chi-sq	Prob.
Excluded		
Excess Liquidity	14.54673	0.0007
Interest Rate	4.047186	0.1322
Inflation	5.647773	0.0594
LREER	6.884282	0.0320
All	34.98735	0.0000
Dependent variable: Inflation	Chi-sq	Prob.
Excluded		
Excess Liquidity	7.518520	0.0233
Interest Rate	2.175140	0.3370
Output Gap	3.317861	0.1903
LREER	7.100046	0.0287
All	24.44205	0.0019
Dependent variable: LREER	Chi-sq	Prob.
Excluded		
Excess Liquidity	7.845826	0.0198
Interest Rate	1.664719	0.4350
Output Gap	0.233211	0.8899
Inflation	1.106313	0.5751
All	12.32488	0.1373

Table 3: VAR Granger Causality / Block Exogeneity Wald Tests

We find statistically significant influences of excess liquidity and the real exchange rate on inflation at the 5 percent significance level. We also note highly statistically significant influences of the output gap and the interest rate on excess liquidity. Moreover, the interest rate is dynamically influenced by excess liquidity and the output gap, whereas for the output gap and the real exchange rate we find a clearly statistically significant influence of excess

liquidity. Moreover, there is a dynamic influence of the real exchange rate on the output gap.

	Excess Liquidity	Interest Rate	Output Gap	Inflation	LREER
Excess Liquidity	1	-0.331	-.280	-.236	.297
Interest Rate	-.331	1	.225	.113	-.259
Output Gap	-.280	.225	1	.050	-.360
Inflation	-.236	.113	.050	1	-.175
LREER	.297	-.259	-.360	-.175	1

Table 4: Correlation Matrix of VAR-Residuals (1976Q3 - 2018Q3)

In addition, an examination of the correlation matrix (Table 2) shows strong contemporaneous relationships between the five variables. In particular, the VAR residuals of excess liquidity and those of IL, YG, INFPY (and the real exchange rate) are strongly negatively (positively) correlated. The most plausible cause of this pattern is the reaction of monetary policy to changes in the output gap and inflation as well as to changes in the real exchange rate.

Given this correlation pattern, we use the following structural VAR model to identify reasonable structural shocks (u) from reduced form shocks (e), $e_t = Bu_t$ with the following zero restrictions:

$$\begin{matrix} x & x & 0 & 0 & x \\ x & x & 0 & 0 & x \\ 0 & 0 & x & 0 & x \\ 0 & 0 & 0 & x & x \\ x & 0 & 0 & 0 & x \end{matrix}$$

This model allows for a simultaneous interdependence between excess

liquidity, the interest rate and the real exchange rate, whereas the reaction of these variables to the output gap and inflation is lagged. Consistent with the monetary literature on monetary policy effects, we find that excess liquidity and the interest rate do not affect inflation and real output contemporaneously. Moreover, the real exchange rate may impact the output gap and inflation immediately.

This model is over-identified and the chi-square test of the corresponding restrictions provides a value of 1.909, which is not statistically significant at the usual significance levels with 3 degrees of freedom (marginal significance level 0.592); thus, the model is validated.

5.2 Excess liquidity dynamics

The impulse responses for the u-shocks with two standard error confidence bands are displayed in Figure 8. We see that most of the impulse responses are statistically significant, and they confirm our a priori expectations.

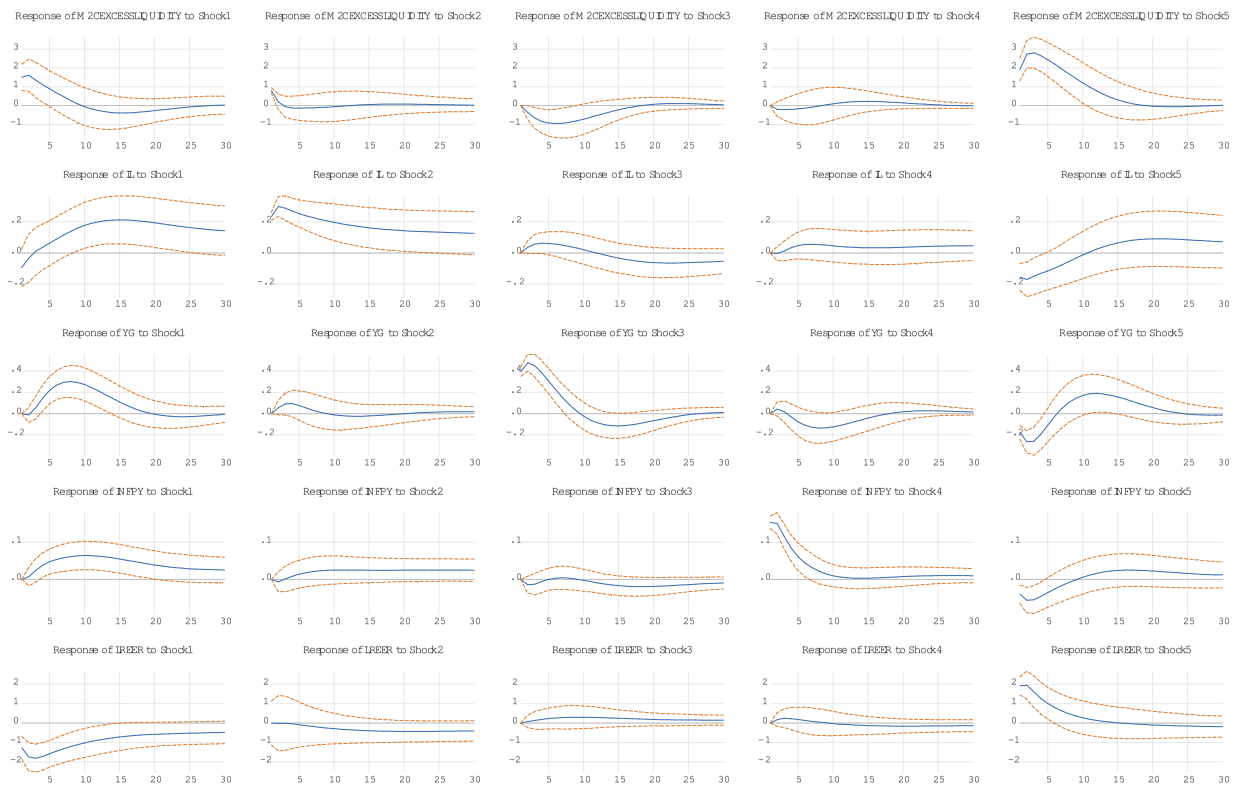

FIG. 8. Impulse Responses, SVAR 1976Q3 - 2018Q3

$u1$ appears as an exogenous change in monetary policy or excess liquidity; it leads to a short-term decrease in the long-term interest rate, which is then reversed by increasing inflation expectations. The output gap and inflation exhibit a hump-shaped adjustment pattern, and this pattern is more delayed and longer lasting for inflation.

These results are consistent with the claims made by Friedman (1968) as well as with the findings of Christiano, Eichenbaum and Evans (2005): after an expansionary monetary policy shock, output and inflation respond with a hump-shaped adjustment pattern. Output peaks approximately one and a half years after the shock and returns to preshock levels after approximately three years, and inflation peaks approximately two years after the shock.

$u2$ is interpreted as a shock to the long rate; however, this shock has no significant effect on output gap, inflation or the real exchange rate. The impulse responses to $u3$ suggest that it is a demand shock that triggers a restrictive monetary policy. $u4$ appears to be a cost-push inflation shock that leads to a restrictive monetary policy and correspondingly to a negative influence on the output gap. Finally, the impulse responses to $u5$ show that an exogenous appreciation of the real exchange rate has a negative influence on the output gap and inflation. An expansive monetary policy mitigates against this change in the real exchange rate, and we see a decline in the interest rate as a result. Note that all the impulse responses converge to zero within 30 quarters; therefore, we see no sign of non-stationarity in our series.

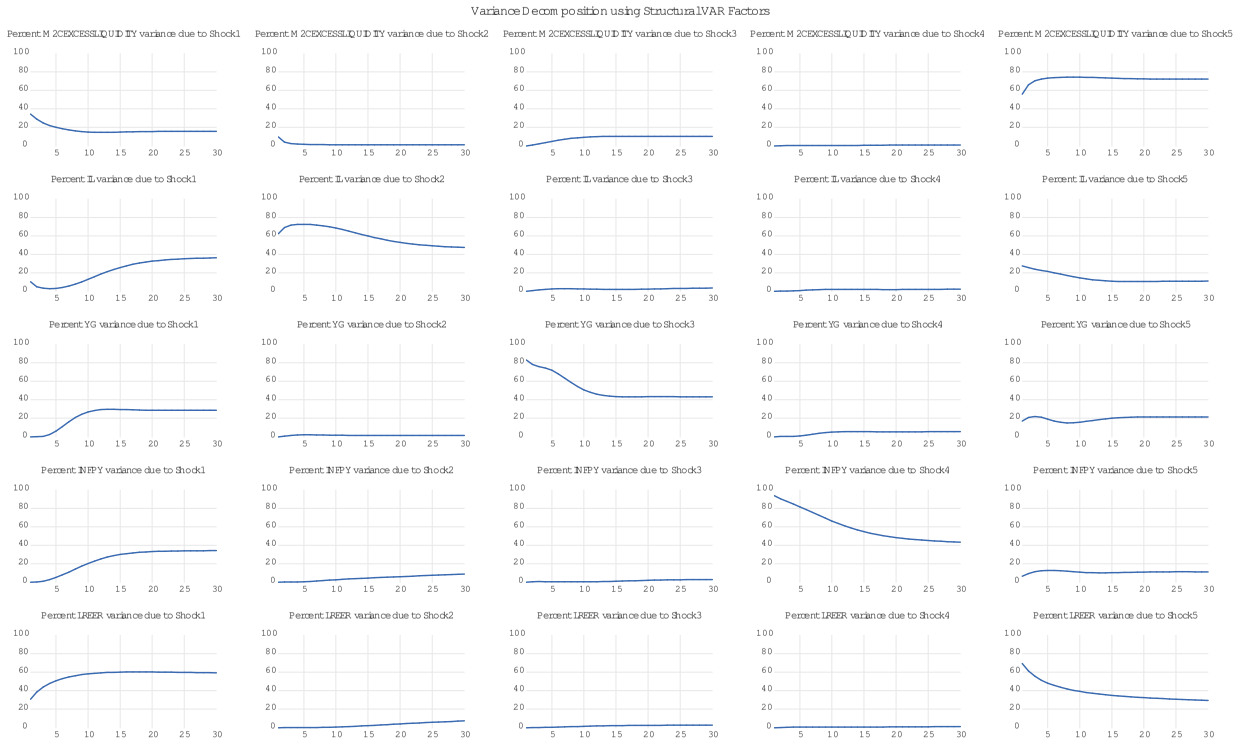

FIG. 9. Variance Decomposition, SVAR 1976Q3 - 2018Q3

The variance decomposition is displayed in Figure 9. This figure shows the percentages of the contributions of all five shocks to the forecasting variance of all the variables for different horizons. In the short term, this variance is mostly dominated by the "own" shock, but the other shocks play an important role in the cases of most of the variables over the long term. This is particularly true for excess liquidity, as the variance share of the exchange rate shock for this variable increases to nearly 70% with an increasing horizon, while the demand shock reaches 10%. This corresponds well with the great importance of the real exchange rate for Swiss monetary policy.

For the output gap and inflation, we observe a long-term variance share of approximately one third for excess liquidity. This is greater than the percentage variance of inflation and output resulting from U.S. monetary policy (interest rate) shocks of 7% and 14%, respectively, which are estimated by Christiano, Eichenbaum and Evans (2005). Moreover, excess liquidity shocks appear very important for the real exchange rate over the long term, as they have a variance share of nearly 60%.

5.3 Robustness tests

To test the stability of our SVAR model over time, we estimated this model using a sample split in 2007Q3. Therefore, we have three estimates, namely, the full sample, 1976Q2 - 2007Q3 and 2007Q4 - 2018Q3. This allows us to calculate a log likelihood for the model with and without a break.

If the hypothesis of no break is correct, then twice the difference of the log likelihood is distributed with 67 degrees of freedom, i.e., the total number

of VAR parameters estimated. As the number of parameters under the alternative hypothesis, i.e., twice the number of VAR parameters, is quite large, we adapt the usual LR statistic formula by replacing the number of observations with the number of degrees of freedom per equation.

This approach produces the test statistic LR = 76.433, which is clearly below the 10% critical value of a chi-squared distribution with 67 degrees of freedom (82.20). Therefore, this result indicates that our model is stable over the past ten years despite the financial and government debt crises as well as the unconventional monetary policy responses to them.

Moreover, we employ an informal check of model stability by calculating the impulse responses (IRs) for the reduced sample covering 1976Q3 - 2007Q3. Figure 10 shows these IRs. In general, the pattern of these responses is very similar to the pattern displayed in Figure 8. This result confirms and illustrates the results of the formal test.

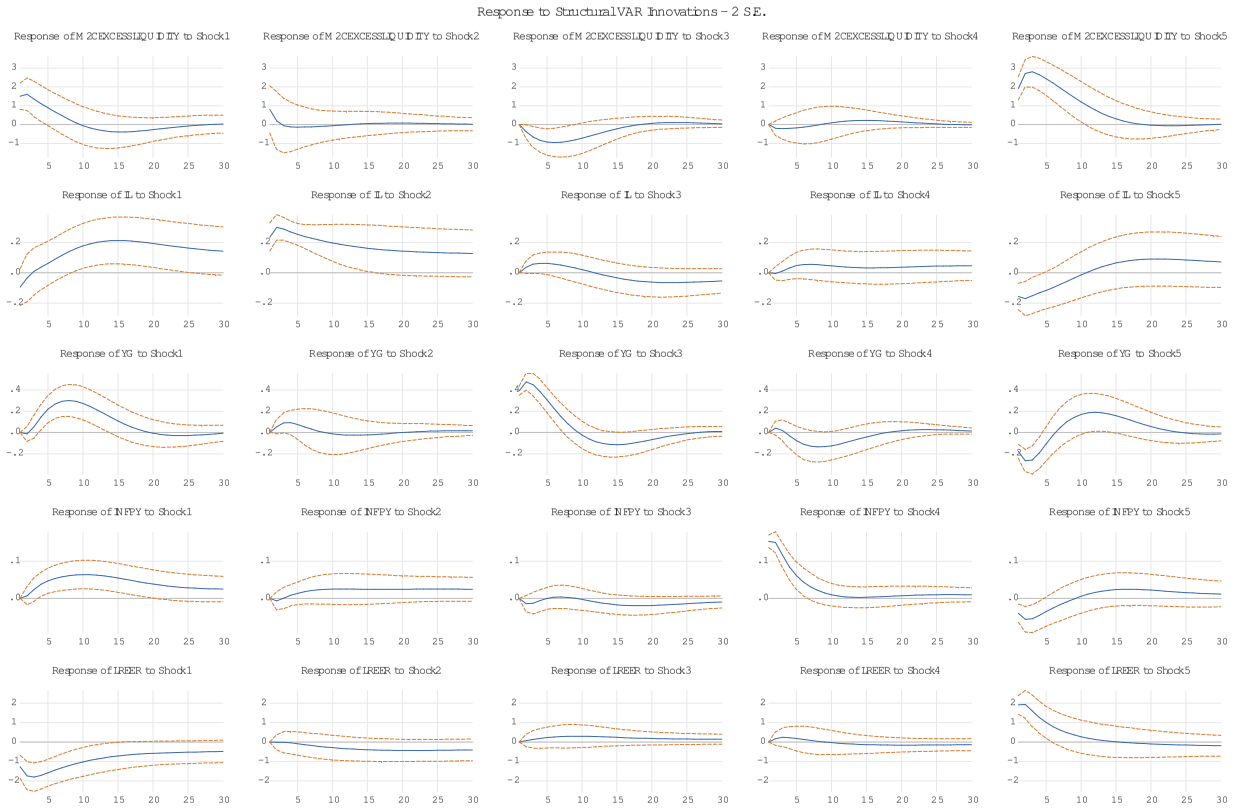

FIG. 10. Impulse Responses, SVAR 1976Q3 - 2007Q3

6 Historical contribution of economic shocks

In this section, we present a historical decomposition of the observed time series that shows the effects of the five structural shocks examined on the development of our variables over time. Burbridge and Harrison (1985) provide a short description of this approach and apply it to the case of the Great Depression in the United States. To this end, we use the impulse response functions to calculate the total effect of the shocks on the observed time series over a specific period.

We choose to employ the entire estimation sample from 1976Q3 to 2018Q3 for this exercise, as this sample covers two major inflation episodes and a subsequent disinflation period. During the first step, we calculate the baseline projection assuming that no shock appears after 1976Q3. Then, we add the shocks occurring during the fourth quarter of 1976 and calculate their contributions to the time series observed. After this, we add the next quarters shocks and calculate their impacts on the variables as well as that of the lagged shocks. We repeat this procedure throughout our sample period.

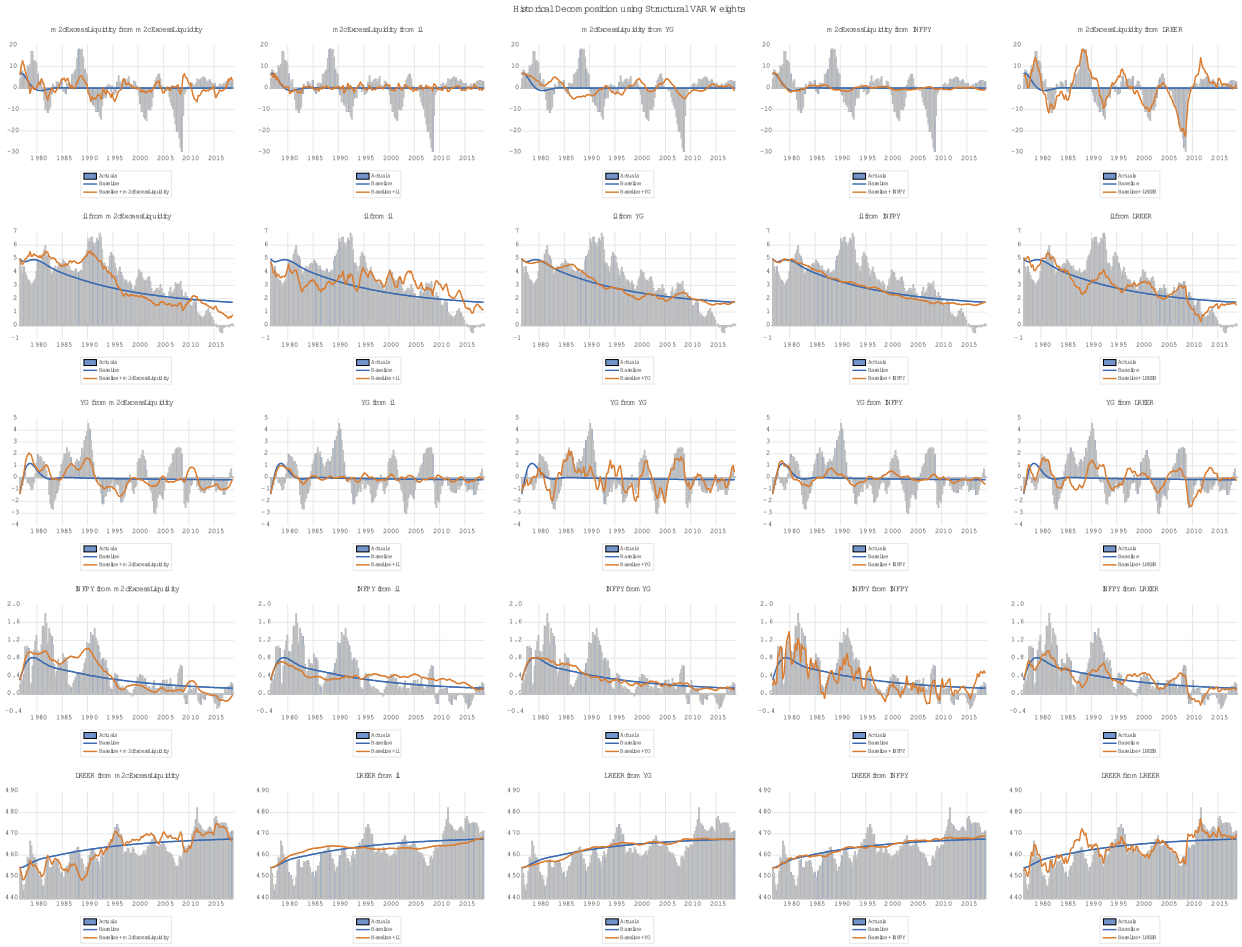

FIG. 11. Historical Decomposition, SVAR 1976Q3 - 2018Q3

Figure 11 shows the results of this exercise. As is the case with the impulse response functions, this figure shows a five-by-five matrix of graphs, with the variables in the rows and the shocks in the columns. The blue line represents the baseline projection, which assumes that there is no shock after our sample begins. The red line displays the contribution of the shock in the column to the observed variable in the row. Finally, the gray bars represent the observed values of the variables. Hence, the red lines in column j show the hypothetical development of all variables if only shock j would have affected the economy and if all the other shocks had been zero.

Here we consider the decomposition of inflation, i.e., the variable of key interest, in detail. Panel 4.1 shows a strong, although not perfect, co-movement of actual and only excess liquidity-caused inflation. The same is true for the cost-push shock *u4* and the real exchange rate shock *u5*, whereas the interest rate shock *u2* and demand shock *u3* lead only to minor deviations from the baseline.

Often, all three of these important shocks move inflation in the same direction, but there are episodes in which opposite impacts are observed. For instance, inflation would have been much higher in the late 1980s with only excess liquidity shocks and without the offsetting real exchange rate appreciation shocks. We also observe fairly strong effects of excess liquidity shocks on the long-term interest rate, output gap and real exchange rate.

Since the financial crisis, the main drivers of negative output gaps and low inflation have been excess liquidity, demand and exchange rate shocks. In a low interest rate environment, negative excess liquidity shocks can occur more frequently than they do in a high interest rate environment, as

the capacity to lower monetary policy interest rates is lessened. Monetary policy can, however, support a small open economy by limiting exchange rate shocks. The SNB's willingness to intervene in the FX market is not modeled here, but it has contributed to the limitation of negative exchange rate shocks, thus contributing to the stabilization of inflation.

The first row of Figure 11 shows that excess liquidity is not greatly affected by exogenous monetary policy or by banking transmission shocks (*u1*). Additionally, excess liquidity is not greatly affected by the interest rate, demand or cost-push shocks either. Not surprisingly, the real exchange rate shock is the main driver of excess liquidity. Exchange rate shocks thus induce monetary policy responses; these responses, through monetary policy transmission via the banking system, can offset the effects of exchange rate shocks on import prices, net exports and output gaps in the highly open Swiss economy.

7 Conclusions

Switzerland represents an interesting case involving special money growth drivers during the recent financial crisis, with robust commercial banks' lending and SNB FX interventions. The relationship between money and inflation that can be observed over the previous three decades has remained stable throughout the decade following the crisis. Inflation has consistently been low and excess liquidity has been low and stable despite the high level of broad money growth, once the continuing decline in the equilibrium velocity and the SNB FX interventions are accounted for.

Our results on the dynamic effects of money on inflation and output are consistent with those of the existing literature. Output and inflation respond with a delay to monetary impulses, with the main impact occurring after approximately two years and additional substantial effects lasting several more years. According to our econometric model, in addition to excess liquidity, which reflects monetary policy actions as well as the banking sector's transmission of monetary policy, exchange rate shocks are the main drivers of inflation in the small open Swiss economy.

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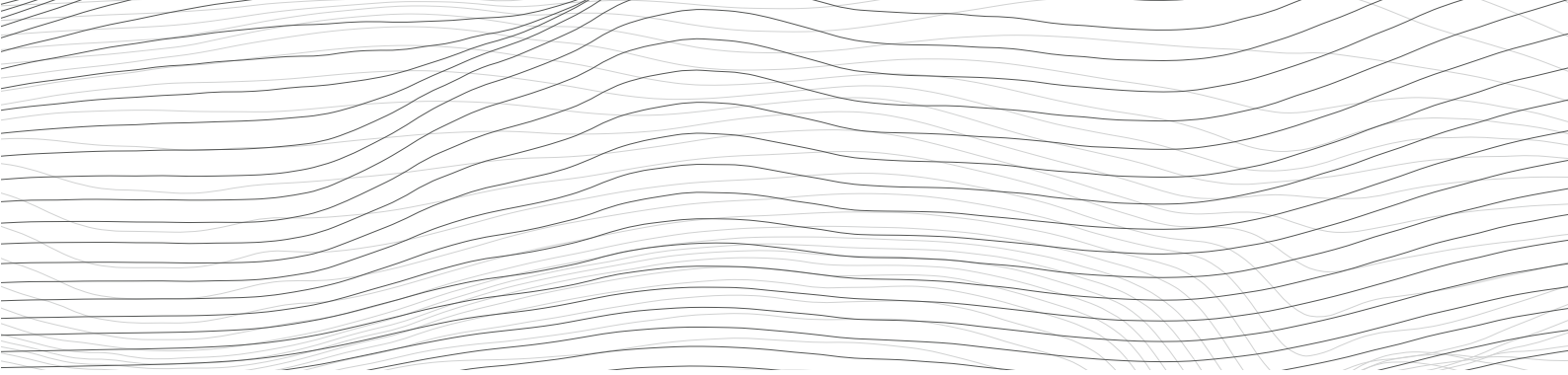

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