Is There a Swiss Price Puzzle?[a]

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1. Introduction

The effect of monetary policy on prices and output is traditionally analysed in vector autoregressions (VARs). A counter-intuitive result emerging in these VARs is that prices tend to increase after a monetary policy tightening; Eichenbaum (1992) referred to this as the price puzzle. The literature has proposed various explanations for this result (for an overview, cf. Walsh, 2003, Chapter 1). One is that prices do indeed rise after a monetary policy tightening because there is a cost channel of monetary policy. Another is that the price puzzle is an econometric artefact. A VAR may be misspecified because it does not include all information that is available to the monetary authority.

The purpose of this paper is to shed light on both arguments by estimating a factor-augmented VAR (FAVAR). Bernanke, Boivin and Eliasz (2005) demonstrate that the FAVAR is capable of eliminating the price puzzle because it includes more information than a traditional VAR. They find no evidence of a price puzzle for the aggregate price level. Using the same method, Boivin, Giannoni and Mihov (2009) examine the responses of disaggregate price

indices to idiosyncratic and macroeconomic shocks. While idiosyncratic shocks are incorporated quickly into prices, macroeconomic shocks have more persistent effects. In this paper, we combine the two contributions and derive disaggregate price responses to a monetary policy shock to examine the price puzzle at the disaggregate level. Because the FAVAR is more robust to misspecification this allows us to identify sectors where the price puzzle emerges from the cost channel of monetary policy.

Our main results can be summarised as follows. At the aggregate level, the price puzzle is an artefact. We do not reject that the price level declines monotonically after a monetary policy tightening. But the decline is delayed by at least four quarters. This result holds, whether we look at the response of the aggregate CPI or at an average response of disaggregate prices. We then show that this is because the FAVAR includes more information than a traditional three-variable VAR.

However, at a disaggregate level, there is evidence for a price puzzle. On the one hand, rents increase significantly after a monetary policy tightening. This is because there are legal provisions in Switzerland which link rents to mortgage rates. On the other hand, we find positive price responses for durable goods. This suggests that a cost channel of monetary policy exists in sectors with larger inventories.

The remainder of this paper is structured as follows. The FAVAR approach and the data are presented in Sections 2 and 3, respectively. Section 4 discusses the results and Section 5 concludes.

2. Methodology

We follow Bernanke, Boivin and Eliasz (2005) and Boivin, Giannoni and Mihov (2009) and use a FAVAR to analyse price responses to a monetary policy shock. Compared to a traditional VAR, the FAVAR exploits the information content of a considerably larger set of macroeconomic variables. In addition, we can analyse the response of any of these variables to an identified monetary policy shock.

We assume that the Swiss economy can be summarised by a vector $\mathbf{C}_t$ of common components following the transition equation

$$\mathbf{C}_t = \Phi(L)\mathbf{C}_{t-1} + \boldsymbol{v}_t, \tag{1}$$

where $\mathbf{C}_t = [\mathbf{F}_t' R_t]'$, $\Phi(L)$ is a lag polynomial and $\boldsymbol{v}_t$ is a zero-mean i.i.d. process. Only one of the common components is perfectly observed; we use the

three-month Libor (3M Libor) as a measure of the monetary policy instrument (R_t).[1] The remaining common components are represented by a vector of unobserved factors $\mathbf{F}_t$, which we extract from a large data set.

The observation equation relates the common components to the data $(\mathbf{X}_t)$

$$\mathbf{X}_t = \Lambda \mathbf{C}_t + \mathbf{e}_t, \tag{2}$$

where Λ is a matrix of factor loadings and $\mathbf{e}_t$ captures idiosyncratic disturbances. This set-up assumes that $\mathbf{X}_t$ are noisy measures of the underlying macroeconomic concepts we aim to estimate. The unobserved factors are extracted as the first K principal components of $\mathbf{X}_t$ (cf. Stock and Watson, 2002). The factor loadings are then estimated using OLS.

Since the 3M Libor is an observed factor, we impose it on the data $\mathbf{X}_t$ as a common component using the recursive procedure suggested by Boivin, Giannoni and Mihov (2009). First, we obtain the first K principal components from $\mathbf{X}_t$, denoted by $\mathbf{F}_t^0$. We then estimate the factor loadings on R_t ($\hat{\boldsymbol{\lambda}}_R^0$) by regressing $\mathbf{X}_t$ on $\mathbf{F}_t^0$ and R_t. Next, we remove the common component of R_t from $\mathbf{X}_t$ by calculating $\tilde{\mathbf{X}}_t^0 = \mathbf{X}_t - \hat{\boldsymbol{\lambda}}_R^0 R_t$. Then, we estimate $\mathbf{F}_t^1$ as the first K principal components of $\tilde{\mathbf{X}}_t^0$. The procedure is repeated several times to obtain the final estimate of $\mathbf{F}_t$.

3. Data

We estimate the FAVAR using a balanced panel of quarterly data from Q1 1978 to Q3 2008. The data include 137 macroeconomic time series and 140 of the price indices underlying the Swiss CPI.[2]

The macroeconomic data set covers many aspects of the Swiss economy such as real activity, the labour market, housing and financial markets. In addition, we include survey information, mostly covering real activity, consumer confidence and price expectations.

The price data set is based on index items obtained from the Swiss Federal Statistical Office (SFSO). An index item is the lowest level at which the SFSO calculates price indices and expenditure weights. We aggregate some of the index

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1   The Swiss National Bank sets an operational target range for its chosen reference interest rate, the 3M Libor (cf. e.g. Jordan, Peytrignet and Rossi, 2010). Usually, it aims to hold the 3M Libor in the middle of that range.

2   A full list of the data and a detailed description of transformations are available upon request.

items to a higher level because the SFSO revised the CPI basket several times during the sample period to adapt the basket to changing consumer preferences.[3] In these revisions, some index items were discarded, added, merged or split up.

Table 1: Average Weights of Price Data

Category	Weight
Total CPI	90.6
Services excluding rents	25.8
Rents	19.5
Non-durable goods	27.9
Semi-durable goods	10.1
Durable goods	7.3

Notes: The table shows average weights for the 140 CPI index items included in the sample. They are aggregated to various sectors and averaged over the sample period.

Our price data cover more than 90% of the Swiss CPI at average weights (cf. Table 1). The remaining 10% are discarded because we are not able to attribute all available index items to one of our categories. Moreover, we exclude administered prices such as public transport fees and postal services.

Although the Swiss CPI is published on a monthly basis, not all prices are actually collected every month. If no survey takes place, the SFSO carries forward the index value of the last month. This hampers transformations such as log differences, seasonal adjustment and aggregation to a quarterly frequency. The SFSO has increased the survey frequency substantially in recent years and most of the CPI basket is now collected monthly.

To account for the irregular survey frequency, we interpolate the missing observations.[4] For every price index we set up a time-series model in terms of the

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3   The Swiss CPI is a Laspeyres index. Therefore, the expenditure weights and the base year change only at major revisions of the CPI basket. To aggregate the index items, we use the corresponding time-varying expenditure weights. For each of our 140 categories, we set the underlying price indices to 100 in the corresponding base years and then take weighted averages. The resulting price indices are then linked in every base year. As of May 2000, the Swiss CPI is a Laspeyres index with weights changing annually.

4   A technical discussion of the interpolation method is available upon request.

unobserved monthly changes. Based on the Kalman filter, we estimate the param-
eters by maximum likelihood (cf. e.g. Hamilton, 1994). The Kalman smoother
yields an estimate of the unobserved monthly changes. Finally, the estimated
monthly changes are transformed back to levels, seasonally adjusted and aggre-
gated to quarterly frequency.

The data should be stationary. We therefore test for unit roots by running an
ADF test (Dickey and Fuller, 1979) and a KPSS test (Kwiatkowski et al.,
1992).[5] Both tests suggest that most of the prices are non-stationary. Therefore
we take log differences of the price data.[6] Moreover, we use log differences of the
macroeconomic time series when the tests suggest that there is a unit root. All
interest rates, spreads and real exchange rates are used in levels.

The question of how many factors to extract from the data can be answered
by the test suggested by Bai and Ng (2002).[7] Because we impose R_t as a common
component, we test for the number of factors in $\tilde{\mathbf{X}}_t = \mathbf{X}_t - \boldsymbol{\lambda}_R R_t$ rather than $\mathbf{X}_t$.[8]
Three factors seem to summarise the information content of $\mathbf{X}_t$ well. Adding
the 3M Libor, we end up with four common components (cf. Figure 1). As
Bernanke, Boivin and Eliasz (2005) emphasise, the test does not tell us how
many factors to include in the VAR to capture the relevant dynamics, but only
how many factors capture the information in the data set well. However, we have
experimented with more factors and the results remain qualitatively the same.

Although we do not strictly identify the factors as economic concepts they seem
to capture at least as much information as a traditional three-variable VAR with
GDP growth, CPI inflation and a short-term interest rate. The absolute size of the
factor loadings give us indications which part of the economy the factors can be
related to (cf. Table 2). The first factor mostly loads on price series. It may there-
fore capture general inflation dynamics. The second factor loads on data covering
the real economy, such as orders, sales or business confidence. Most of the factor
loadings are negative, that is, the factor is negatively correlated with real activ-
ity. This is also supported by the fact that the factor is strongly correlated with
one of the output gap measures calculated regularly by the Swiss National Bank

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5   The test results are available upon request.
6   The ADF test has low statistical power to identify unit roots, so we visually inspect those prices
    for which the test rejects a unit root; they often appear to be non-stationary. We therefore use
    log differences for all prices.
7   We apply the first criterion proposed by Bai and Ng (2002). The other two criteria imply the
    same number of factors.
8   Stock and Watson (2005) recommend a similar procedure when imposing a lag on the obser-
   vation equation.

Table 2: Largest Loadings Sorted by Absolute Size

Factor 1 (inflation)		Factor 2 (real activity)		Factor 3 (world activity)		Factor 4 (3M Libor)	
2.4	Manufacturing: technical production capacities[s]	-2.7	Manufacturing: business sentiment[s]	-2.5	PMI United States	-1.2	Manufacturing: technical production capacities[s]
2.4	Other cheese[p]	-2.6	Manufacturing: outstanding orders[s]	-2.4	Morgan Stanley Capital International: world	-1.1	Japanese yen in Swiss francs (real)
2.3	Hard cheese[p]	2.6	Manufacturing: inventories final goods[s]	-2.4	Residential building	1.0	10 year confederation bond yield
2.2	Package holidays[p]	-2.5	Wholesale: business sentiment[s]	-2.4	Swiss Market Index	-0.9	Butter[p]
2.2	Japanese yen in Swiss francs (real)	-2.5	Consumer sentiment: past economic development[s]	-2.3	GDP United States	-0.9	Banknotes in circulation
2.1	Plants and flowers[p]	-2.5	Consumer sentiment[s]	-2.3	World trade	0.9	Mortgage rates by cantonal banks
2.1	Bed and household linen[p]	-2.5	Wholesale: sales to previous year[s]	2.2	First aid material[p]	-0.9	Prices for single family homes
2.1	Swiss red wine[p]	2.1	Wholesale: delivery lags to previous year[s]	-2.2	GDP	-0.9	Spread (10 year confederation bond – 3M Libor)
2.1	Outstanding domestic mortgage credit	2.1	Manufacturing: expected activity[s]	-2.2	UBS 100 index	0.8	Manufacturing: revenues[s]
2.0	Prices for rental apartments	-2.3	Manufacturing: expected purchases of intermediate goods[s]	-2.1	Morgan Stanley Capital International: Switzerland	-0.8	Consumer sentiment: past financial situation[s]

Factor 1 (inflation)		Factor 2 (real activity)		Factor 3 (world activity)		Factor 4 (3M Libor)	
2.0	Butter^p	−2.3	OECD composite leading indicator^s	−2.0	Manufacturing: technical production capacities^s	−0.8	Prices for owner-occupied apartments
2.0	CPI^p	−2.3	Manufacturing: outstanding orders to previous month^s	−2.0	Exports	−0.7	Residential building
2.0	Furnishings^p	2.3	Manufacturing: inventories intermediate goods^s	−2.0	Industrial production	0.7	Kitchen utensils^p
1.9	Prices for single family homes	−2.3	Wholesale: expected delivery lags^s	−2.0	Footwear for children^p	−0.7	Consumer sentiment: expected financial situation^s
1.9	Dried, frozen and tinned vegetables^p	−2.3	Manufacturing: revenues^s	−1.9	Imports	0.7	Tools for DIY and garden^p

Notes: The table gives the 15 largest factor loadings sorted by absolute size for each factor. The superscripts p and s denote consumer prices and surveys, respectively.

Figure 1: Estimated Factors

(a) Factor 1

(b) Factor 2
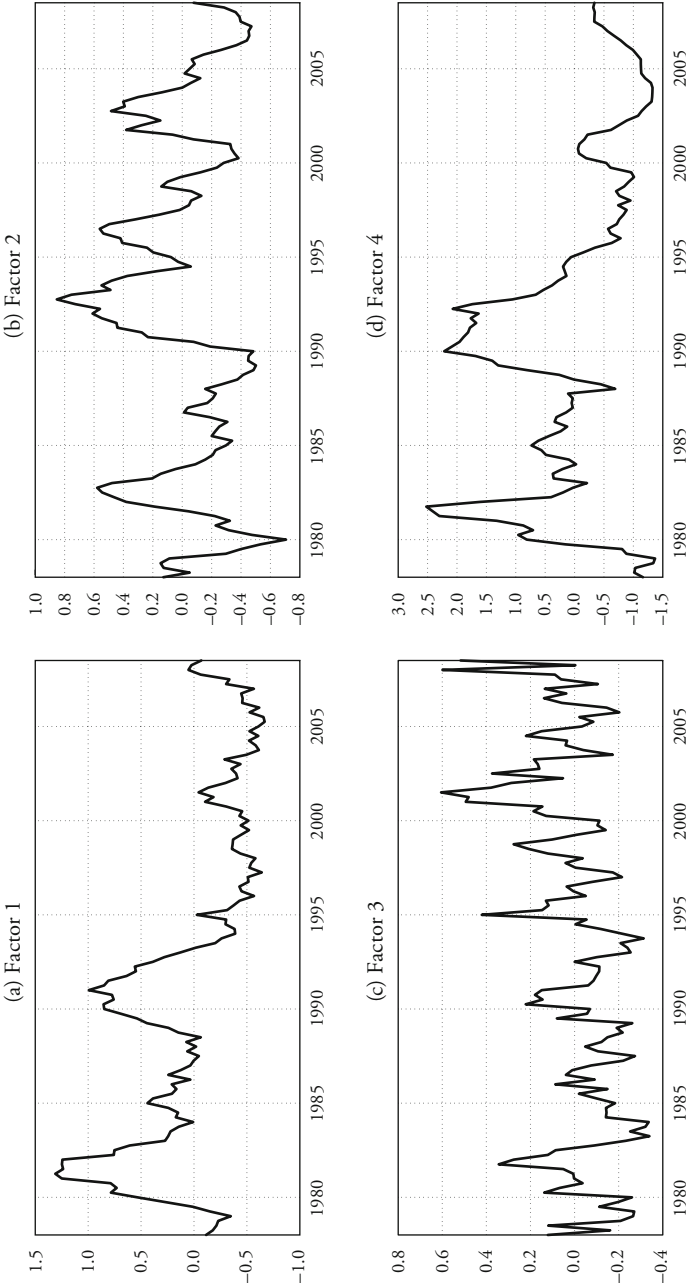
(c) Factor 3

(d) Factor 4

Notes: The figures display the estimated factors used in the FAVAR. Factor 1 mostly loads on prices, factor 2 on (inverse) real activity and factor 3 on (inverse) world activity. Factor 4 shows the normalised 3M Libor.

(contemporaneous correlation: −0.66; two quarters ahead correlation: −0.78). The third factor mostly loads on international data and Swiss data related to world activity. Again, most factor loadings are negative. By construction, the fourth factor is the 3M Libor. It loads not only on the interest rate spread, mortgage rates and residential building, but also on technical capacities and price series.

4. Results

The FAVAR allows us to analyse the effect of monetary policy on a large number of variables. The transition equation (1) is estimated with five lags and the monetary policy shock is identified by recursive ordering.[9] We assume that the monetary policy shock does not affect the common components within one period. Thus, monetary policy surprises take some time to be reflected in slow-moving variables such as real activity or inflation; but the monetary authority can react immediately to changes in the economic environment.

### 4.1 VAR Misspecification

Many studies suggest that the price puzzle is due to VAR misspecification. These studies avoid the price puzzle by including a commodity price index (SIMS, 1992; EICHENBAUM, 1992), money (LEEPER and ZHA, 2001; ASSENMACHER-WESCHE, 2008), an output gap (GIORDANI, 2004) or inflation expectations (CASTELNUOVO and SURICO, 2010). The FAVAR encompasses these arguments because it includes more information than a traditional VAR.

The impulse responses of the factors to a 25 bp increase in the 3M Libor are broadly in line with economic intuition (cf. Figure 2).[10] The factor mostly loading on prices exhibits a hump-shaped response (panel a). That is, it first rises but then declines after roughly four quarters. Although there is no sustained positive response, this indicates that some prices in our sample may still exhibit a price puzzle. As one would expect, the factor that is inversely related to real activity

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9 In what follows, we define the monetary policy shock as a surprise increase in the 3M Libor. However, the impulse responses for a decrease are symmetric in our set-up.

10 80% and 90% confidence intervals are given as shaded areas. They are derived via the bias-corrected bootstrap algorithm proposed by KILIAN (1998). We ignore the fact that the factors are estimated and therefore subject to uncertainty. However, the confidence intervals are still correct if the number of time series in X_t is large relative to the number of time periods (cf. BAI and NG, 2004).
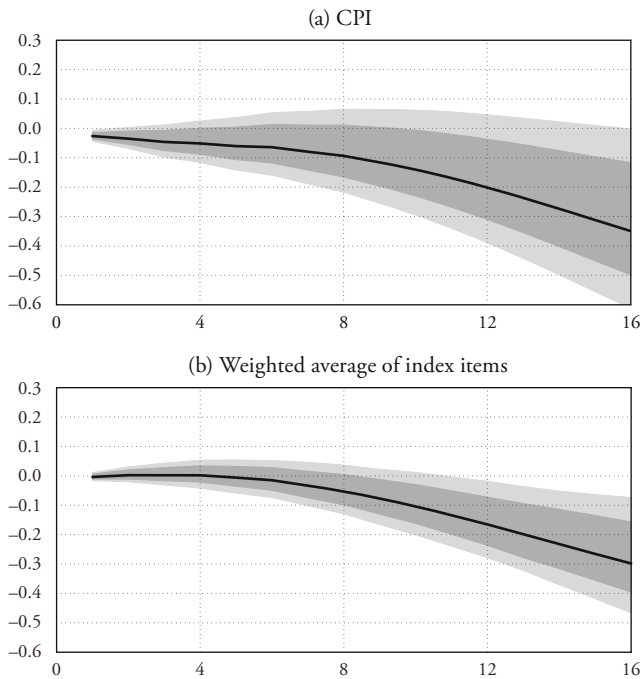
Figure 2: Factor Responses

(a) Factor 1

(b) Factor 2
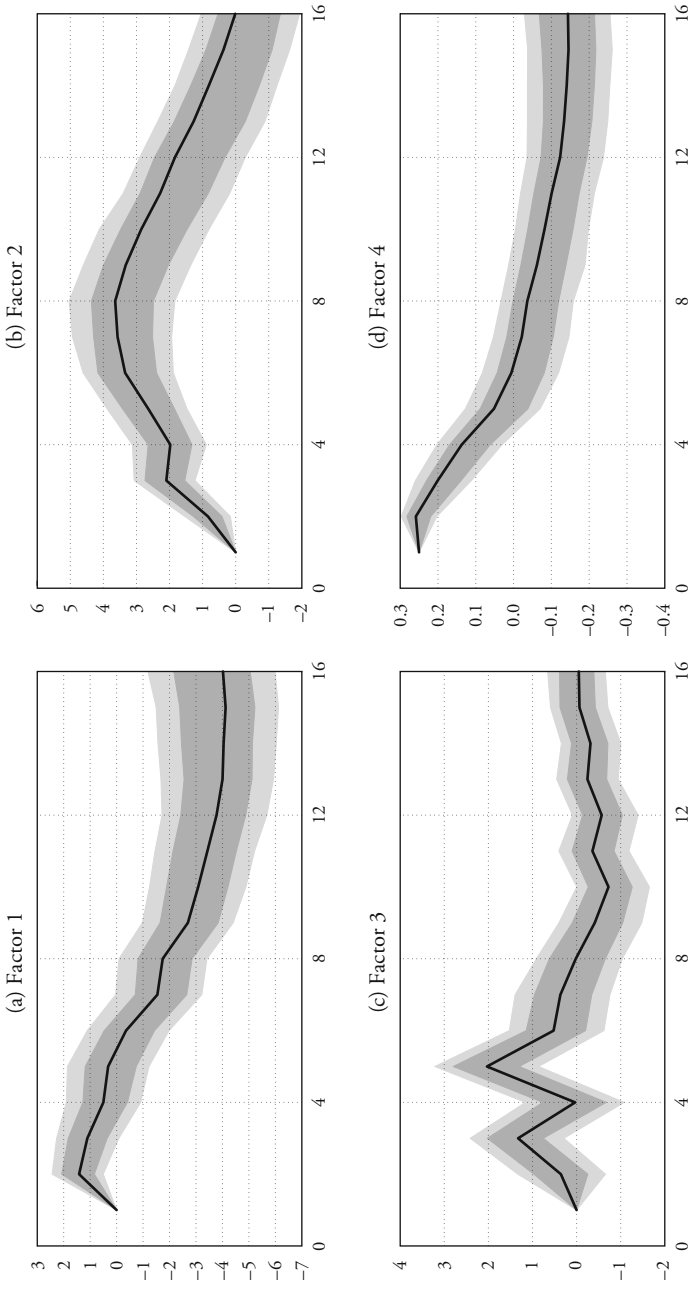
(c) Factor 3

(d) Factor 4

Notes: The figures display impulse responses to an identified monetary policy shock along with 80% and 90% confidence intervals. The monetary policy shock is a surprise increase of 25 bp in the 3M Libor. Factor 1 mostly loads on prices, factor 2 on (inverse) real activity and factor 3 on (inverse) world activity. Factor 4 is the 3M Libor.

increases after a contractionary monetary policy shock (panel b). While prices appear to be permanently reduced, there is only a transitory effect on real activity. Factor 3 does not react systematically to a monetary policy shock (panel c). The 3M Libor displays some inertia after the initial shock. It first moves sideways and then returns to zero after six quarters (panel d).

Figure 3: Response of the CPI

(a) CPI

(b) Weighted average of index items

Notes: The figures display accumulated impulse responses to an identified monetary policy shock along with 80% and 90% confidence intervals (in percent). The monetary policy shock is a surprise increase of 25 bp in the 3M Libor.

From these factor responses, we can calculate the responses of specific variables in our data set via observation equation (2).[11] Figure 3 illustrates the response of the aggregate price level to a monetary policy shock. Although the response is sluggish, there is no evidence of a price puzzle (panel a). Looking at the weighted

11 More precisely, we calculate the response of the common component of these variables.

average response of the 140 index items corroborates this finding (panel b). Focusing on the point estimate, we find a response that is delayed by four quarters. But we would not reject that a monetary policy shock may take even longer to affect prices.[12]

It is possible that we do not find a price puzzle because the FAVAR includes more information than a traditional VAR. To examine this possibility, we augment a three-variable VAR with our estimated factors. Our FAVAR nests this VAR, and therefore we can assess whether the additional information reduces the price puzzle (cf. Bernanke, Boivin and Eliasz, 2005).

The results suggest that the price puzzle is an econometric artefact because we do not include enough information in a traditional three-variable VAR. Figure 4 displays the responses for a VAR with GDP growth, CPI inflation and the 3M Libor (solid lines). The CPI rises permanently after a contractionary monetary policy shock, and thus there is a price puzzle. However, if we augment the VAR with one or two factors, the price puzzle disappears (dashed and dotted lines). Meanwhile, the responses of GDP and the 3M Libor are not greatly affected.

4.2 Swiss Rent Law

Although the price puzzle disappears for the aggregate CPI, we still find positive price responses in some sectors. In particular, the initial rise in rents can be explained by legal provisions in Switzerland.

Switzerland is special in that rents under existing contracts are partially linked to mortgage rates by law. Owners of a rental apartment have to adjust rents under existing contracts when mortgage rates change. Thus, interest rate movements may feed directly into the CPI. Moreover, rents are partially indexed to the CPI. This may have an additional reinforcing effect.

Rents pick up by almost 0.2% after a monetary policy tightening (cf. Figure 5, panel a). This coincides with mortgage rates rising by 12 bp on impact (panel b). Rents thus partly explain the delayed response of the CPI to a monetary policy shock. The CPI excluding rents (panel c) shows a faster decline than the total CPI (cf. Figure 3).

A 12 bp increase in mortgage rates would, by law, allow for a 1% increase in rents, which is five times larger than what we estimate. First, this is because the law covers only rents under existing contracts. There is more leeway to set rents

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12 This is in line with the idea that prices are adjusted irregularly. Kaufmann (2009) finds that the average duration between two price adjustments is slightly more than one year.

Figure 4: VAR Augmented with Factors
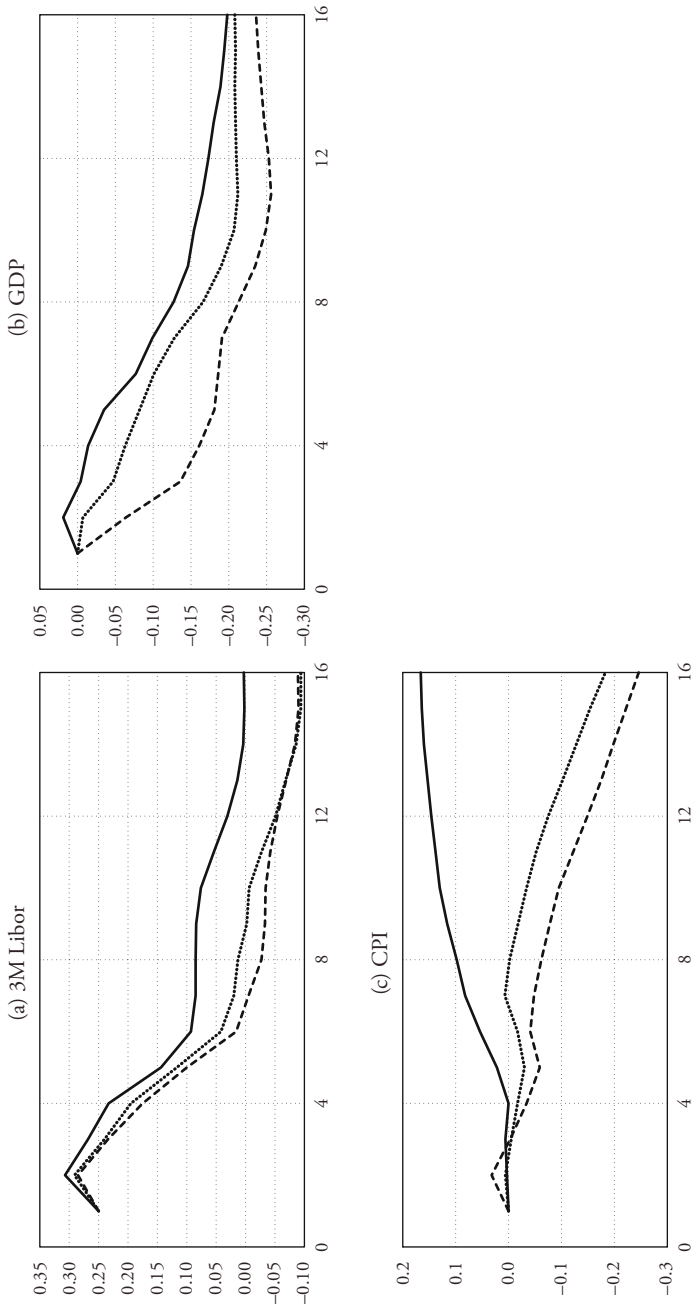
(a) 3M Libor

(b) GDP

(c) CPI

Notes: The figures display accumulated impulse responses to an identified monetary policy shock (in percent). The first VAR is estimated on CPI inflation, GDP growth and the 3M Libor (solid line). The second and third VARs (dashed and dotted lines) additionally include one and two factors. The monetary policy shock is a surprise increase of 25 bp in the 3M Libor.

Figure 5: Rents and Mortgage Rate
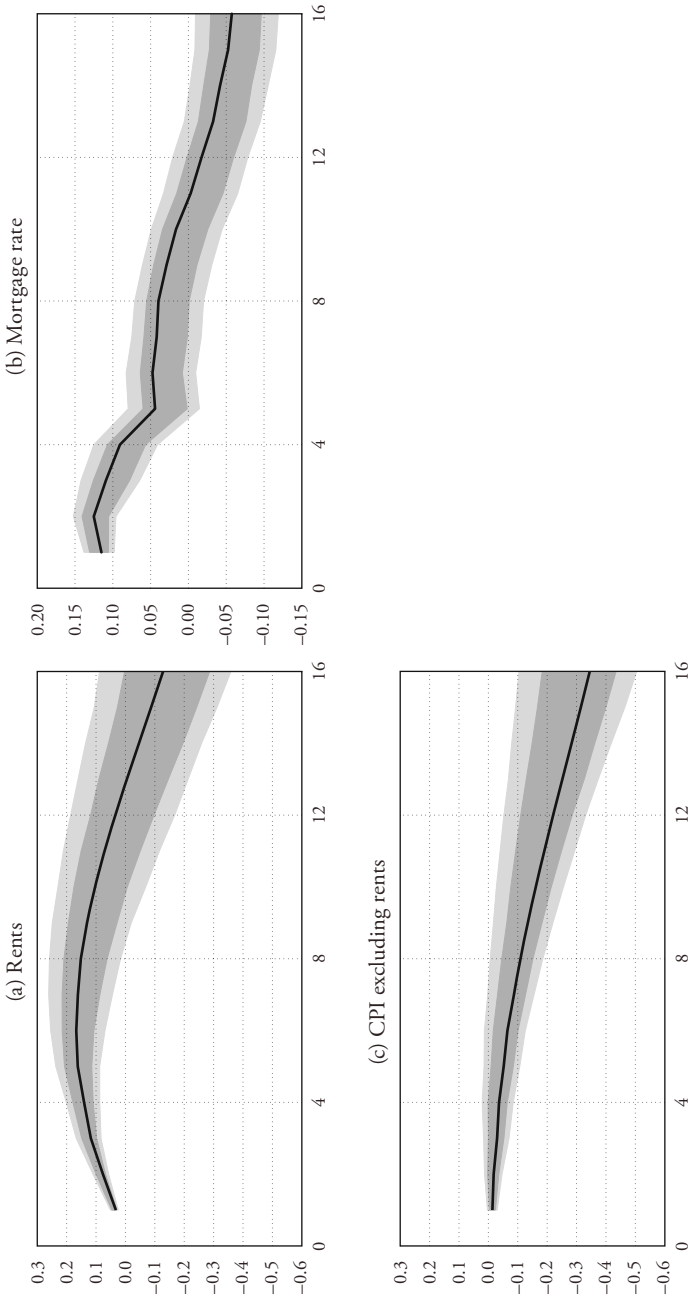
(a) Rents

(b) Mortgage rate

(c) CPI excluding rents

Notes: The figures display accumulated impulse responses to an identified monetary policy shock along with 80% and 90% confidence intervals (in percent). The monetary policy shock is a surprise increase of 25 bp in the 3M Libor.

under newly negotiated contracts. Second, this is because there is no automatic adjustment; the owner or tenant has to file an application with the corresponding counterparty. Our estimates suggest this right is rarely exercised. STALDER (2003) also finds that mortgage rate changes do not fully feed into higher rents. According to his estimates, a 10 bp increase in mortgage rates leads to a 0.23% increase in rents on impact and a 0.49% increase in the long term.

4.3 Cost Channel

Although rents explain a major part of the delayed response of the Swiss CPI, durable goods also display a price puzzle. They show a significant short-run increase and start to fall after eight quarters (Figure 6, panel a). By contrast, other prices do not exhibit a sustained increase in the price level. Prices for services excluding rents display the most sluggish behaviour and decline only after eight quarters. Meanwhile, semi-durable goods prices start to decline after one year and non-durable goods prices decline immediately.

How can we explain the hump-shaped responses for durable goods? Theoretically, a hump-shaped price response may occur if higher interest rates translate into higher marginal costs of production. This is called the cost channel of monetary policy transmission.[13] One explanation of the cost channel mechanism is that firms have to pre-finance inventories via financial intermediaries. Thus, higher interest rates feed into higher prices as the real cost of inventories tends to increase in response to a monetary policy tightening. Arguably, inventory holdings are more important for durable goods than for non-durable goods, semi-durable goods and services. Therefore, durable goods may be particularly affected by the cost channel of monetary policy transmission.

This finding is in line with recent work using DSGE models. HENZEL et al. (2009), for instance, show for the euro area that, although the cost channel does not produce a hump-shaped response, it helps to explain a delayed price response. Our results are consistent with this. While there is no price puzzle at the aggregate level, we find that in sectors where inventory holdings play a larger role, a hump-shaped response emerges that leads to a more sluggish response of the aggregate price level.

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13 For theoretical and empirical results on the cost channel of monetary policy transmission cf. e.g. BARTH and RAMEY (2002), RAVENNA and WALSH (2006), CHOWDHURY, HOFFMANN and SCHABERT (2006), RABANAL (2007), TILLMANN (2008) and HENZEL et al. (2009).

Figure 6: Goods and Services Excluding Rents
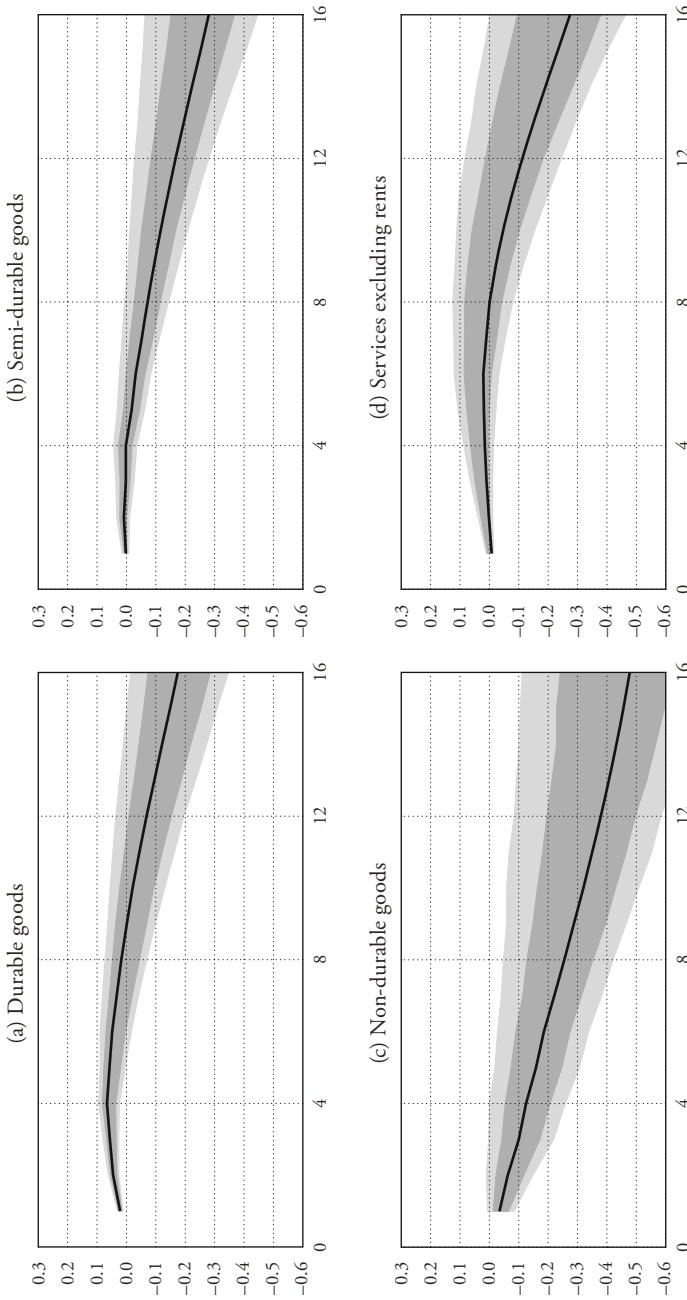
(a) Durable goods

(b) Semi-durable goods

(c) Non-durable goods

(d) Services excluding rents

Notes: The figures display accumulated impulse responses to an identified monetary policy shock along with 80% and 90% confidence intervals (in percent). The monetary policy shock is a surprise increase of 25 bp in the 3M Libor. The impulse responses are aggregated from the disaggregate price responses using the average CPI expenditure weights over the estimation period.

5. Conclusions

This paper identifies monetary policy shocks in a FAVAR for Switzerland. In line with findings for the US, the response of the aggregate CPI to a monetary policy shock no longer displays a price puzzle when using a FAVAR. The aggregate CPI starts to fall four quarters after the monetary policy tightening. This is because the FAVAR includes more information than a traditional VAR and therefore avoids misspecification.

We take the analysis a step further and show that there remains a price puzzle in some sectors. First, the price puzzle is partly a result of legal provisions in Switzerland that link rents to mortgage rates. Therefore, the CPI excluding rents declines faster after a monetary policy tightening than the aggregate CPI.

Second, prices of durable goods also rise after a monetary policy tightening. This may be related to the cost channel of monetary policy. One explanation of the cost channel mechanism is that firms have to pre-finance inventories via financial intermediaries. Thus, higher interest rates feed into higher prices as the real cost of inventories tends to increase in response to a monetary policy tightening. Arguably, inventory holdings are more important for durable goods than for non-durable goods, semi-durable goods and services. Therefore, durable goods may be particularly affected by the cost channel of monetary policy transmission. As argued in theoretical work using DSGE models, the existence of a cost channel in a single sector does not necessarily lead to a rising aggregate price level; but the response of the aggregate price level to a monetary policy shock may then be more delayed.

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SUMMARY

This paper estimates the response of consumer prices to a monetary policy shock in Switzerland. We find that there is no evidence of a price puzzle at the aggregate level. This is because our factor-augmented vector autoregression (FAVAR) avoids misspecification by including more information than a traditional VAR. However, the response is still delayed by at least four quarters, partly because there is a price puzzle in some sectors. In particular, rents tend to rise after a monetary policy tightening because there are legal provisions in Switzerland which link them to interest rates. But durable goods prices also rise, which is consistent with the existence of a cost channel of monetary policy.