International inflation spillovers - the role of different shocks

Gregor Bäurle, Matthias Gubler and Diego R. Känzig

SNB Working Papers
7/2017

SCHWEIZERISCHE NATIONALBANK
BANQUE NATIONALE SUISSE
BANCA NAZIONALE SVIZZERA
BANCA NAZIUNALA SVIZRA
SWISS NATIONAL BANK

Legal Issues

ISSN 1660-7716 (printed version)
ISSN 1660-7724 (online version)

International inflation spillovers – the role of different shocks*

Gregor Bäurle†, Matthias Gubler‡, and Diego R. Känzig§

Abstract

We analyze how the transmission of international inflation spillovers depends on the nature of the underlying shocks that drive inflation abroad. We find evidence for substantial heterogeneity in the magnitude of spillovers to domestic inflation related to the fundamental source of international price fluctuations and the corresponding monetary policy reactions. Indeed, it turns out that the relative conduct of monetary policy varies depending on the source of these price fluctuations, and so does the role of the exchange rate as a shock absorber. We show this by looking at international inflation spillovers to Switzerland through the lenses of a Bayesian structural dynamic factor model relating a large set of disaggregated prices to key macroeconomic factors. Being a small open economy with an independent monetary policy, Switzerland is a particularly suitable subject for studying the role of monetary policy in the transmission of foreign shocks. However, our results more broadly indicate that inflation spillovers need to be analyzed in a framework allowing for different transmission channels.

JEL classification: C11, C32, E31, E52, F62

Keywords: international spillovers, inflation, monetary policy, Bayesian factor model, sign restrictions

*We thank Carlos Lenz, Ana Mitreska, Paolo Surico, an anonymous referee and the participants at the SNB Brown Bag Seminar, the CFE conference 2015 in London, the SSES meeting 2016 in Lugano, the EEA conference 2016 in Geneva, and the NBP-SNB joint seminar 2017 in Zurich for useful comments and suggestions. The views, opinions, findings, and conclusions or recommendations expressed in this paper are strictly those of the authors. They do not necessarily reflect the views of the Swiss National Bank. The SNB takes no responsibility for any errors or omissions in, or for the correctness of, the information contained in this paper. A previous version of this paper circulated under the title "Does independent monetary policy shield against international spillovers to inflation? An empirical study with Swiss data".

†Swiss National Bank, Economic Analysis, P.O. Box, CH-8022 Zurich, Switzerland, e-mail: gregor.baeurle@snb.ch

‡Swiss National Bank, Inflation Forecasting, P.O. Box, CH-8022 Zurich, Switzerland, e-mail: matthias.gubler@snb.ch

§London Business School, London NW1 4SA, UK, e-mail: dkaenzig@london.edu

1 Introduction

The world has moved closer together along many dimensions in recent decades. However, increased economic integration goes hand-in-hand with potentially major international spillover effects. Therefore, a deep understanding of spillovers is key to ensuring optimal policy decisions, particularly in open economies with strong international ties. From a monetary policy perspective, the transmission of international spillovers to consumer prices is of particular interest.

So far, overall empirical evidence on the impact of spillovers to domestic inflation dynamics is ambiguous. Some authors find that "inflation is largely a global phenomenon" (Ciccarelli and Mojon 2010) suggesting that "domestic inflation rates may (at least partly) escape the control of national central banks" (Monacelli and Sala 2009), while others document that the importance of domestic output gaps for inflation has not diminished due to increased globalization (see, e.g., overview in Rieth 2015). This ambiguity may arise from time-varying spillover effects (Mumtaz and Surico 2012), from cross-country variation in the relative importance of spillovers (Neely and Rapach 2011), or the aggregation level of inflation (Monacelli and Sala 2009).

In this paper, we stress the importance of a further explanation for the varying strength of international spillover effects. Traditionally, flexible exchange rates in tandem with independent monetary policy are thought to be effective in cushioning the effect of international shocks on the domestic economy (see, e.g., Woodford 2007). However, movements in the exchange rate depend crucially on the relative reaction of foreign and domestic monetary policy. If the relative conduct of monetary policy varies depending on the fundamental source of price fluctuations, so does the role of the exchange rate as a shock absorber. As a result, domestic inflation may be affected differently depending on the shock originally driving foreign price fluctuations.

To empirically assess the role of this channel, we analyze how different shocks driving up Consumer Price Index (CPI) inflation in the euro area (Switzerland's largest trading partner) translate into inflationary pressures in Switzerland, putting particular emphasis on the relative monetary policy responses and the corresponding exchange rate fluctuations. We argue that the Swiss case is of particular interest in this context because

Switzerland has had numerous and deep trade links, has been exposed to large cross-border capital flows grounded on free movement of capital, and has had a flexible exchange rate. Furthermore, the fact that economic conditions in Switzerland, a small open economy, are unlikely to impact global economic conditions simplifies the analysis as it allows one to identify a causal effect of foreign price fluctuations.

Our empirical framework relies on a dynamic factor model relating a large set of disaggregated Swiss consumer prices to the key euro area as well as Swiss macroeconomic factors. It proves useful to integrate a large set of disaggregated Swiss consumer prices into the analysis because CPI components may react very differently to the shocks we consider (see also Monacelli and Sala 2009, Mumtaz and Surico 2009 or Boivin et al. 2009). The model is estimated by Bayesian methods on quarterly data for the period from 1992Q1 to 2011Q2, i.e., the sample ends prior to the introduction of the minimum exchange rate of CHF 1.20 per euro on 6 September 2011. We then identify three structural shocks that are driving up inflation in the euro area, namely a positive demand, an expansionary monetary policy, and a cost-push shock, and we study how they are transmitted to the Swiss economy.

We find that foreign shocks explain up to approximately 50% of Swiss price variations, while common domestic shocks account for approximately 20% (the remaining part being due to item-specific shocks). Thus, domestic inflation is, to a substantial degree, driven by foreign factors. However, this does not imply that Swiss monetary policy has not been able to affect international spillover effects to domestic inflation. Spillover effects on Swiss prices depend on the nature of the underlying shocks because their transmission varies – among other factors – with the distinct euro area and Swiss monetary policy responses. Following an increase in inflation in the euro area due to a positive demand shock, euro area monetary policy counteracts the business cycle upturn strongly, while the Swiss monetary policy reaction turns out to be less restrictive. As a consequence of the change in the relative monetary policy stance, the Swiss franc depreciates and inflation picks up even somewhat more than in the euro area. In contrast, in response to an increase in inflation in the euro area due to an expansionary monetary policy shock, monetary policy becomes relatively tighter in Switzerland. As a result, the Swiss franc appreciates, mitigating spillover effects to Swiss inflation. Finally, a cost-push shock driving up inflation (and decreasing real activity) in the euro area has no significant effects on the relative monetary policy stance. As a consequence, the effects on the exchange rate turn out to be negligible and the increase in Swiss inflation is comparable to that in the euro area. These results indicate that spillover effects need to be analyzed in a framework allowing for different transmission channels: an increase in inflation abroad may affect inflation in an open economy differently, depending on the source of the foreign shock and, thus, movements in other factors such as interest and exchange rates. This may also partly explain the ambiguity of the empirical evidence found so far.

The analysis of the different items of the Swiss CPI points to substantial heterogeneity in the transmission of international spillovers. It turns out that energy prices play a crucial role. The impact of foreign inflationary shocks on the Swiss CPI is markedly lower, and the transmission appears to be slower when energy prices are excluded. Furthermore, there is some heterogeneity in the transmission to the prices of imported goods, domestic goods and services, which are likely related to differences in tradability and exchange rate sensitivity. While we find short to medium-run changes in relative prices in response to the foreign shocks, we do not find significant effects on relative prices in the long run, in line with previous findings in the literature (Mumtaz and Surico 2009, Boivin et al. 2009). This further underlines the importance of the relative stance of monetary policy through its effect on the exchange rate.

Overall, we conclude that international spillovers are substantial. Therefore, monetary policy has to take into account foreign factors in fulfilling its mandate. At the same time, the relative stance of monetary policy of Switzerland vis-à-vis the euro area is an important determinant of the magnitude of the spillovers. In that sense, independent monetary policy does, at least to some extent, shield against them.

Our results turn out to be robust along a number of dimensions, including the specification of the foreign model block. The results based on a global foreign block consisting of export-weighted indicators of Switzerland's major trading partners are qualitatively in line with the results for the euro area, suggesting that our findings do not uniquely pertain to spillovers from the euro area to Switzerland but to international inflation spillovers to Switzerland more generally.

The remainder of this paper is organized as follows. Section 2 overviews the related literature. In section 3, we cover our econometric approach, including details about the modeling framework, the model specification, and the data as well as the estimation and identification strategy. In section 4, we present the results and discuss their implications. Section 5 concludes the paper.

2 Related literature

This paper is related to several studies that explore the impact of international factors on country-specific inflation from different angles. In their seminal paper, Ciccarelli and Mojon (2010) quantify the comovement between global inflation and CPI inflation rates in OECD countries. They find that country-specific inflation rates are largely a global phenomenon, i.e., individual countries tend to inherit global inflationary pressures. Building on this study, Mumtaz and Surico (2012) show that the properties of global inflationary pressures vary over time and shed some light on economic characteristics driving differences and similarities across country-specific inflation rates. Neely and Rapach (2011) detect economic policies and development measures, which explain the cross-sectional variation in the relative importance of international influences. More recently, Altansukh et al. (2017) note that the globalization in long-run inflation is largely driven by the convergence in the mean levels of the core component and the short-run globalization effect can be traced back to the energy component. Various other recent studies focus on the impact of specific global factors, reflecting commodity prices or global business cycles, on domestic inflation dynamics with ambiguous empirical evidence (see Rieth 2015, for a brief literature review). Auer et al. (2017a,b) document the importance of global value chains as transmission channels of global factors to domestic inflation.

Our work is also related to a strand of the literature assessing the international transmission of structural shocks. Several studies have attributed an important role to external shocks in explaining domestic macroeconomic fluctuations. Many of these studies gauge the evolution of the impact of international spillovers originating from the United States, with a special focus on U.S. monetary policy shocks (see, e.g., Georgiadis 2016, Maćkowiak 2007, Canova 2005, or Kim 2001). In a more recent study, Potjagailo (2017) analyzes the spillover effects from euro area monetary policy shocks across a range of

EU countries. She finds heterogeneous spillover effects on prices across countries and asymmetric inflation responses in most Central and Eastern European countries.

Our analysis is most similar in spirit to the studies by Mumtaz and Surico (2009) and Aastveit et al. (2016). Mumtaz and Surico (2009) use a FAVAR to examine the dynamic effects of global shocks on the UK economy.[1] Aastveit et al. (2016) add regional factors to the global factors and extend the set of countries examined (Canada, New Zealand, Norway and the UK). Our analysis differs from these studies in a number of dimensions, including the dataset and the country analyzed, but also the structure of the model and the estimation method. Most importantly, however, we specifically aim at shedding light on the question of whether and how monetary policy of a small open economy reacts to international spillovers to inflation. Moreover, it puts particular emphasis on potential differences in the transmission of foreign shocks to different items of the CPI. Hałka and Kotłowski (2016) also provide a detailed analysis of the role of global shocks on disaggregated price dynamics in three small open economies other than Switzerland (Czech Republic, Poland and Sweden), but based on a different modeling approach.

This paper contributes to the literature by showing that spillovers need to be analyzed in a framework allowing for different transmission channels for a better understanding of their effects. Our conclusion that spillover effects depend on the underlying shock and multiple transmission channels is also in line with recent evidence of Forbes et al. (2015) on the exchange rate pass-through in the UK. They argue that the size of the exchange rate pass-through to consumer prices depends on the source of the shock moving the exchange rate.

3 Econometric approach

To study the potential spillover effects of foreign inflationary pressures on the Swiss economy and in particular on Swiss prices, we set up a structural dynamic factor model for the Swiss economy. The model relates a large set of disaggregated price data to the key domestic and foreign macroeconomic factors. Building on the framework proposed by Bäurle and Steiner (2015), it takes into account the characteristics of a small open economy.

[1] Liu et al. (2014) extend their study by analyzing changes over time in those effects on the UK economy using a time-varying FAVAR approach.

The structural shocks are identified using two different types of restrictions. First, we exploit that economic conditions in Switzerland, a small open economy, are unlikely to impact global economic conditions. This allows us to separate foreign from domestic shocks. Second, we use sign restrictions motivated by economic theory to disentangle different types of foreign shocks.

3.1 Modeling framework

A dynamic factor model is a framework relating a large panel of economic indicators to a number of observed and unobserved common factors. The premise behind this type of model is that the economy can be characterized by a limited number of factors that drive the comovements of the indicators in the panel. Formally, the model consists of two different equations: an observation equation and a state equation. The observation equation relates the panel of economic indicators X_t^S to the common factors f_t that drive the economy:

$$X_t^S = \lambda(L) f_t + v_t, \tag{1}$$

where $\lambda(L) = \lambda_1 + \lambda_2 L + \lambda_3 L^2 + \ldots + \lambda_q L^q$ are the factor loadings, L is the lag operator, and v_t is a vector of item-specific components. Thus, the indicators X_t^S are allowed to load on the factors both contemporaneously and on their lags. Following Boivin and Giannoni (2006), we allow v_t to be autocorrelated of order one by specifying $v_t = \psi v_{t-1} + \xi_t$ with $\xi_t \sim N(0, R)$. For our specific application, X_t^S compromises a large number of disaggregated data on Swiss consumer prices. To make our model suitable for a small open economy, we partition the common factors f_t into two blocks: a foreign and a domestic block. The domestic block is further partitioned into a block of unobserved factors and a block of observed factors. Hence, the common factors can be written as $f_t = (f_t^{S'},\ X_t^{M'},\ X_t^{M*'})'$, where f_t^S are the domestic unobserved common factors, X_t^M are the domestic observed common factors, and X_t^{M*} are foreign observed common factors. The joint dynamics of these factors are described by the following state equation:

$$\phi(L) f_t = Q \varepsilon_t, \tag{2}$$

where $\phi(L) = I - \phi_1 L - \phi_2 L^2 - \ldots - \phi_p L^p$ are coefficient matrices, ε_t is a vector of common structural shocks, and Q is the structural impact matrix. The shocks ε_t are assumed to be Gaussian white noise, i.e., $\varepsilon_t \sim N(0, I)$. Moreover, the common shocks ε_t and the idiosyncratic shocks ξ_t, which we call item-specific shocks, are postulated to be uncorrelated. The vector of common shocks ε_t can be partitioned into vectors of foreign shocks ε_t^{M*} and domestic shocks ε_t^{M}, whose dimensions correspond to X_t^{M*} and X_t^{M}, respectively. The small open economy assumption is then implemented by modeling the foreign block of the model as exogenous to the Swiss economy. To this end, we assume that foreign variables do not react to domestic shocks at all lags by restricting $\phi(L)$ and the covariance matrix Q appropriately. More precisely, we restrict the block of $\phi(L)$ that relates X_t^{M*} to the lags of X_t^{M} and the elements of Q that relate X_t^{M*} to the domestic shocks ε_t^{M} to zero.

3.2 Specification and data

Our baseline specification includes six observed common factors. As discussed above, these factors are grouped into two blocks: a foreign and a domestic one. The foreign block contains measures for output, the short-term interest rate, and consumer prices. The domestic block consists of the same type of measures except consumer prices because they are implicitly contained in the disaggregated price data. To link the domestic to the foreign economy, we also include the nominal exchange rate.

As discussed in Bäurle and Steiner (2015), the selection of the remaining model dimensions is not trivial. As a benchmark, we set the number of unobserved factors to one and the lag order in the state and the observation equation to $p = 2$ and $q = 1$, respectively. Later, we will check the robustness of our results with respect to these dimensions.

Because the euro area is Switzerland's most important trading partner, we choose it as the foreign block of the model. For the measures of output, short-term interest rates, and consumer prices, we use euro area real GDP, the 3M Euribor, and euro area CPI, respectively. For Switzerland, we use Swiss real GDP and the 3M Libor. Finally, the EURCHF is selected as the relevant nominal exchange rate. The exchange rate is quoted indirectly; hence, a positive exchange rate change implies an appreciation of the Swiss franc. For the disaggregated price data, we rely on a panel of 148 Swiss CPI items.[2] The frequency of the data is quarterly, and the sample spans the period from 1992Q1 to 2011Q2. We choose this particular sample period because it was characterized by a relatively stable monetary policy regime and flexible exchange rates, which is important as our model does not allow for time-variation in the model parameters. All variables enter the model as quarter-on-quarter (qoq) growth rates except for the interest rates, which enter in levels. Following the literature, the series are standardized such that they have zero mean and a variance equal to one. After estimation, the quantitative results are transformed back into the original scale.

It is important to note that despite not including Swiss CPI inflation explicitly as an observed factor in the state equation, the remaining factors contain almost all consumer price information. Figure 1 shows Swiss CPI inflation (qoq) together with the fitted values of the following OLS regression:

$$\pi_t = \beta f_t + u_t. \tag{3}$$

One sees that the fit based on the seven factors in the benchmark model (the six observed factors and the unobserved factor) is excellent, matching basically all peaks and troughs, with an R^2 of slightly above 75%.

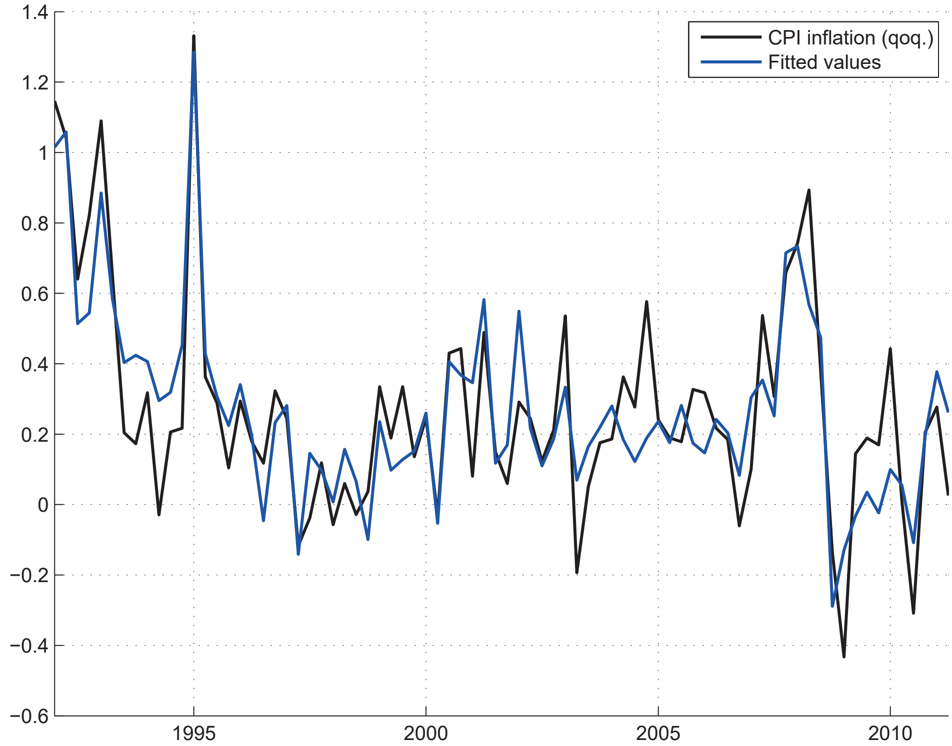
3.3 Estimation

The model is estimated using Bayesian methods. Because it is not possible to derive analytical results for high-dimensional estimation problems such as the one at hand, we have to rely on numerical techniques to approximate the posterior. In particular, we use a Gibbs Sampler, iterating over the following two steps (, e.g., Kim and Nelson 1999). First, for a given (initial) set of model parameters, a realization of the distribution of the factors conditional on this set of parameters is drawn. Given this draw, a new set of parameters can be drawn from the distribution of parameters conditional on the draw of the factors.

The two steps are repeated $J = 100,000$ times. From these draws, we discard the first 20,000 to assure that the chain has converged to its ergodic distribution. Geweke's

[2] The panel is constructed from item-level price data collected by the Swiss Federal Statistical Office (SFSO). A more detailed description of the disaggregated price data can be found in Appendix A.

Figure 1 – Swiss CPI inflation (qoq) versus fitted values



Note: The figure illustrates Swiss CPI inflation (qoq) and the fitted values of an OLS regression of Swiss CPI inflation on one unobserved factor and six observed factors. The observed factors are euro area real GDP, the 3M Euribor, euro area CPI, the EURCHF, Swiss real GDP, and the 3M Libor. All observed variables enter the model as quarter-on-quarter growth rates except for the interest rates, which enter in levels.

spectral-based measure of relative numerical efficiency (RNE, see, e.g., Geweke 2005) suggests that efficiency loss of the algorithm due to the remaining autocorrelation in these evaluated draws is minimal.[3] The efficiency loss is less than 50% for almost all of the parameters, i.e., vis-à-vis a hypothetical independence chain, and we need no more than 50% additional draws to achieve the same numerical precision. Moreover, the maximum inverse RNE is 4.6, which is well below the value of 20 that is mentioned in the literature as a critical threshold (see, e.g., Carriero et al. 2014, Baumeister and Benati 2013 or Primiceri 2005). Additionally, we use Geweke (1992)'s test to assess the convergence of the algorithm, confirming that posterior means for partitions of the chain do not differ.[4]

[3]The spectrum at frequency zero is calculated using a quadratic spectral kernel as described in Neusser (2009)

[4]We follow Geweke (1992) and test whether the parameter means based on the first 10^{th} of the draws (after discarding the burn-in sample) are significantly different from the second half of the draws.

We also investigate convergence visually by looking at the posterior means based on an expanding number of draws, finding no evidence of changes after less than half of the draws.

Our choices for the prior distributions are the following. The prior for the coefficients in the observation equation is proper. This mitigates the problem that the likelihood is invariant to an invertible rotation of the factors. The problem of rotational indeterminacy in this Bayesian context is discussed in detail in Bäurle (2013).[5] The determination of the coefficients describing the factor dynamics reduces to the estimation of a standard VAR. We implement the restrictions reflecting the exogeneity assumption on foreign factors following Karlsson (2013) and Bauwens et al. (1999). Furthermore, we impose stationarity by rejecting the draws that do not satisfy the stationarity condition. It is important to note that the likelihood is only informative about $\Sigma = QQ'$, but not about Q directly. Therefore, we first derive the posterior distribution of Σ and impose certain restrictions based on economic considerations to pin down the distribution of Q in a second step. The strategy for identifying Q depends on the specific application and is described in the subsequent subsection. As compared to the procedure in Bäurle and Steiner (2015), we implement two changes to the prior distribution. Both changes help us to make the estimation procedure more robust especially in short samples. First, we assume that a priori, the variances of the parameters in $\lambda(L)$ are decreasing with the squared lag number. Second, we assume a Minnesota-type prior for the parameters in the state equation as described in Karlsson (2013). We set the hyper-parameter as follows: in Karlsson (2013)'s notation, we use $\pi_1 = \pi_2 = \pi_3 = 1$ to implement a very loose prior and set the prior mean of the first own lag to zero as we model stationary series. Further details on the estimation method and the implementation can be found in Appendix B.

3.4 Identification

To analyze how foreign inflationary pressures affect the Swiss economy, we identify three different foreign inflationary shocks: a demand shock, a monetary policy (MP) shock, and

[5]Bayesian analysis is always possible in the context of nonidentified models as long as a proper prior on all coefficients is specified, see, e.g., Poirier (1998). Note that rotating the factors does not have an impact on the impulse response functions as long as no restrictions on the responses of the factors to shocks are set.

a cost-push shock, all originating in the euro area. The shocks are identified using two different types of restrictions. First, we exploit that economic conditions in Switzerland are unlikely to have an impact on economic conditions abroad. Thus, domestic shocks are restricted to have no effect on foreign variables as implemented by short-run zero restrictions on Q. In this way, domestic shocks are separated from foreign ones. Note that in combination with the restrictions on $\phi(L)$ described in Subsection 3.1, domestic shocks do not influence foreign variables at all lags. Second, we use sign restrictions to disentangle the different types of foreign shocks. Following Uhlig (2005), we restrict the sign of the response of selected elements of X^M_{t+h}, but do not directly impose restrictions on the reaction of X^S_{t+h}. Specifically, we assume that a positive shock to foreign demand leads to an increase in output, prices, and the real interest rate (nominal interest rate minus CPI inflation) in the euro area. In contrast, an expansionary foreign monetary policy shock is assumed to decrease the policy rate and to increase output and prices in the euro area. Finally, we assume that a cost-push shock in the euro area causes output to fall and foreign prices to rise. An overview of the sign restrictions used can be found in Table 1. It is important to note that we place restrictions only on the responses of foreign factors and remain agnostic about the reaction of the domestic economy as well as the exchange rate. As a benchmark, we impose these restrictions for $h \leq 1$ periods.[6]

Table 1 – The identification scheme

Variable/Shock	Demand	Monetary policy	Cost-push
Real GDP growth euro area	$+$	$+$	$-$
Policy rate euro area	$(+)$	$-$	$*$
CPI inflation euro area	$+$	$+$	$+$
Real interest rate euro area	$+$	$(-)$	$*$

We chose this identification scheme with short-run and sign restrictions because it is well established in the literature and theoretically founded. To check whether the identification scheme makes sense, we also compute the contributions of the structural foreign shocks and the domestic shocks to quarterly changes in the de-trended levels of the Swiss real

[6] This horizon is consistent with the horizon chosen by Uhlig (2005), who uses 5 periods with monthly data.

GDP, the Swiss CPI and the EURCHF as well as the de-trended level of the 3M Libor.[7] The results point to reasonably identified shocks as shown in Figure 2. For example, positive foreign demand shocks contributed strongly to real GDP growth in Switzerland and also supported Swiss CPI inflation in the period from around 2006 to 2008. During that period, real GDP growth in the euro area was particularly strong. The same is true for the early-2000s. At the end of 2007 and the beginning of 2008, Swiss inflation picked up due to cost-push shocks. In this period, the oil price increased strongly, before collapsing right after the onset of the financial crisis. This is reflected in negative cost-push shocks in late 2008. At that time, negative foreign demand shocks and restrictive monetary policy shocks also weighed on Swiss inflation.

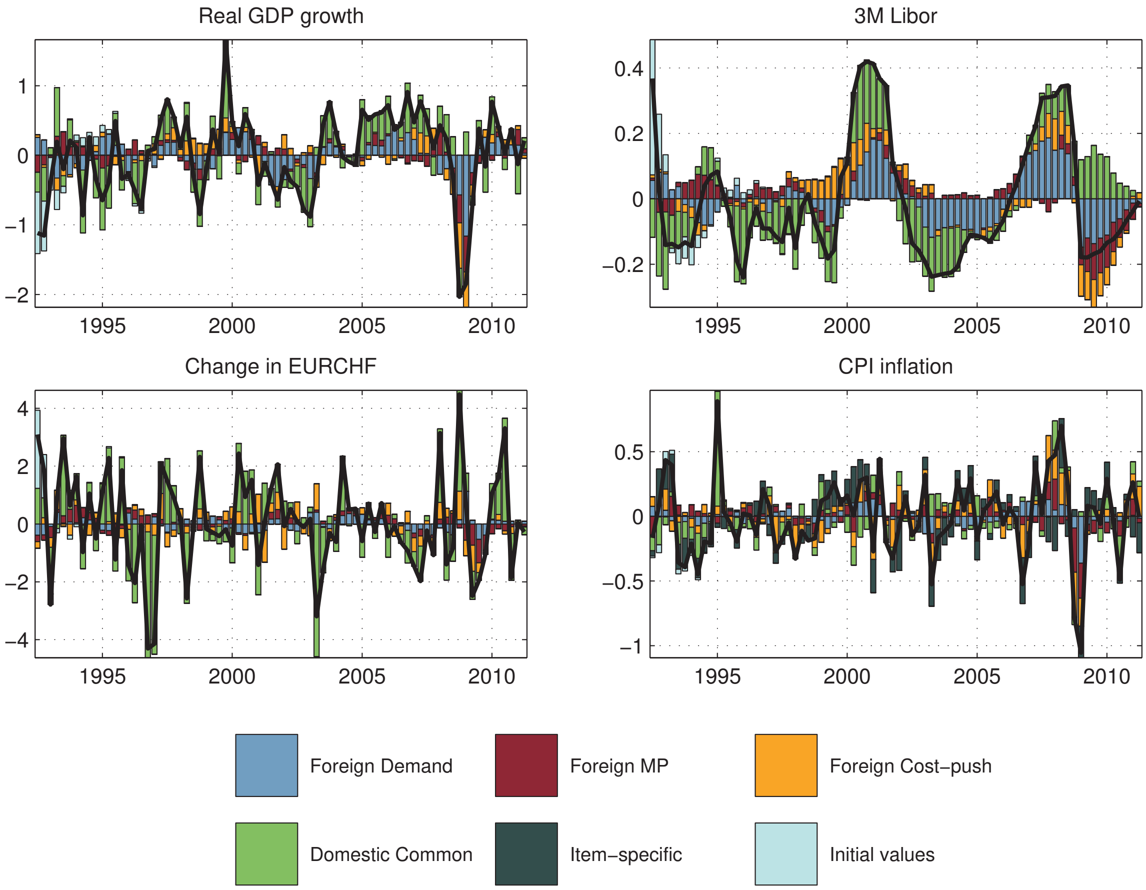
To implement the sign restrictions conditional on the zero restrictions, we use the method proposed by Arias et al. (2014). Based on the draws that satisfy the identification scheme, we compute statistics that facilitate the interpretation of the results. In particular, we look at impulse response functions (IRFs) and the fraction of forecast error variance decomposition (FEVD). Highest probability density (HPD) intervals on these statistics are calculated 'pointwise', i.e., for each horizon separately.

4 Results

In this section, we present the results of our empirical analysis. We start by discussing the transmission of inflationary shocks in the euro area to the Swiss economy. Subsequently, we will analyze the quantitative importance of foreign and domestic shocks on a set of Swiss macroeconomic variables – with a specific focus on consumer prices. After having studied the effects at the aggregate level, we will investigate heterogeneities in the transmission of spillovers. Finally, we will check the robustness of our results and discuss the implications for monetary policy.

[7] All variables are de-trended with the use of the Hodrick-Prescott filter. Note that the variables are not de-trended in the benchmark model. However, as shown in the robustness analysis, de-trending the variables does not alter our conclusions.

Figure 2 – Historical decomposition of de-trended Swiss macroeconomic variables



Note: The figure shows the historical contributions of the structural foreign shocks and the domestic shocks to quarterly changes in the de-trended levels of the Swiss real GDP, the Swiss CPI and the EURCHF as well as the de-trended level of the 3M Libor. All variables are de-trended with the use of the Hodrick-Prescott filter.

4.1 Spillovers from the euro area to the Swiss economy

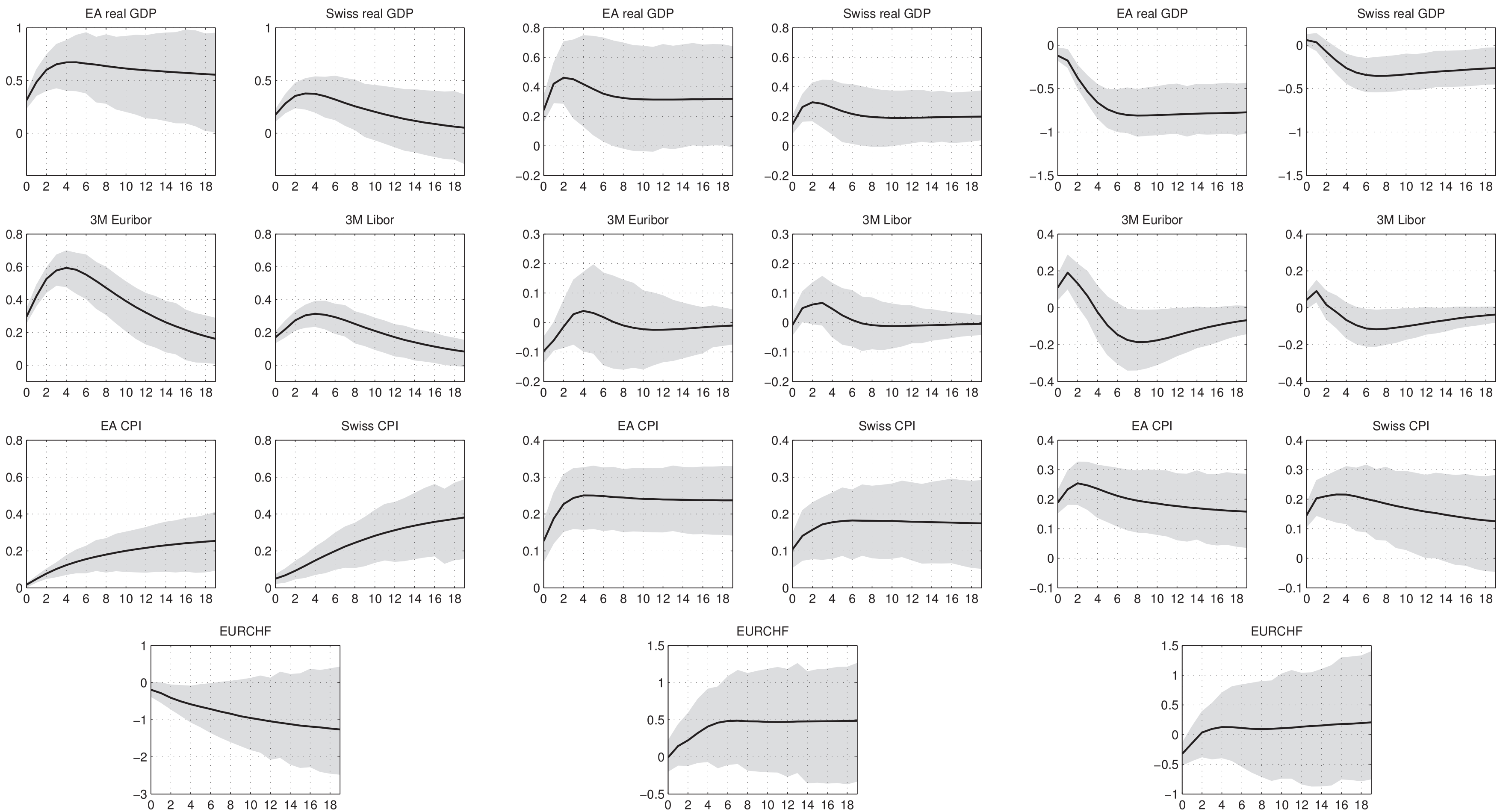
How do foreign inflationary pressures originating from different shocks in the euro area impact upon the Swiss economy and in particular upon Swiss prices? We analyze this question by looking at the impulse responses to the identified shocks. We study how the shocks affect the euro area before turning to the analysis of the spillover effects to Switzerland. This helps to assess whether the shocks are identified correctly. The impulse responses to the three identified foreign shocks – demand, monetary policy and cost-push shocks – are presented in Figure 3. In addition, Figure 4 shows the responses of the CPI, nominal and real interest rate spreads between the euro area and Switzerland to these shocks. The median response is depicted by the bold black line. The light gray shaded areas represent 68% HPD intervals. Cumulative responses are shown for all variables except the interest rates. The response of the Swiss CPI is calculated based on the disaggregated price responses and the corresponding CPI weights.

Response to foreign demand shocks A positive shock to demand in the euro area leads to a persistent rise in foreign output, consumer prices, and the real interest rate – consistent with our identifying restrictions. The demand driven boom in the euro area has substantial spillover effects on the Swiss economy. Both Swiss output and prices rise strongly, consistent with the fact that Switzerland is an open economy and thus heavily dependent on the foreign economic development. However, while the demand driven upturn is counteracted by substantial hikes in policy rates in the euro area, the Swiss monetary policy reaction turns out to be less restrictive (as reflected by a weaker response of the real interest rate) as shown in Figure 4. These changes in the relative monetary policy stance induce the Swiss franc to depreciate against the euro, which in turn leads to significant pass-through effects to Swiss consumer prices. While Swiss consumer prices initially increase more sluggishly, the Swiss CPI attains a higher level than that of the euro area in the long run (see Figure 4). While prices of domestic and imported items rise on a broad base, prices of imported goods rise particularly strongly (see Figure 10 in Appendix C for the impulse responses of different price categories to the three structural shocks).

Response to foreign monetary policy shocks By construction, an expansionary monetary policy shock in the euro area leads to a fall in the 3M Euribor stimulating consumption and investment, which in turn causes output and consumer prices to increase. The economic upturn initiated by the expansionary monetary policy shock also has substantive effects on Switzerland: both output and prices increase significantly. In contrast to what we observe in response to foreign demand shocks, however, the monetary policy stance becomes relatively more restrictive in Switzerland for approximately one year. Consequently, the Swiss franc appreciates, cushioning the spillover effects to Swiss prices, and Swiss consumer prices rise less than in the euro area, as shown in Figure 4.

Figure 3 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI

Positive Demand — Expansionary Monetary Policy — Cost-push



Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The responses of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. All other responses along the y-axis denote percentage changes.

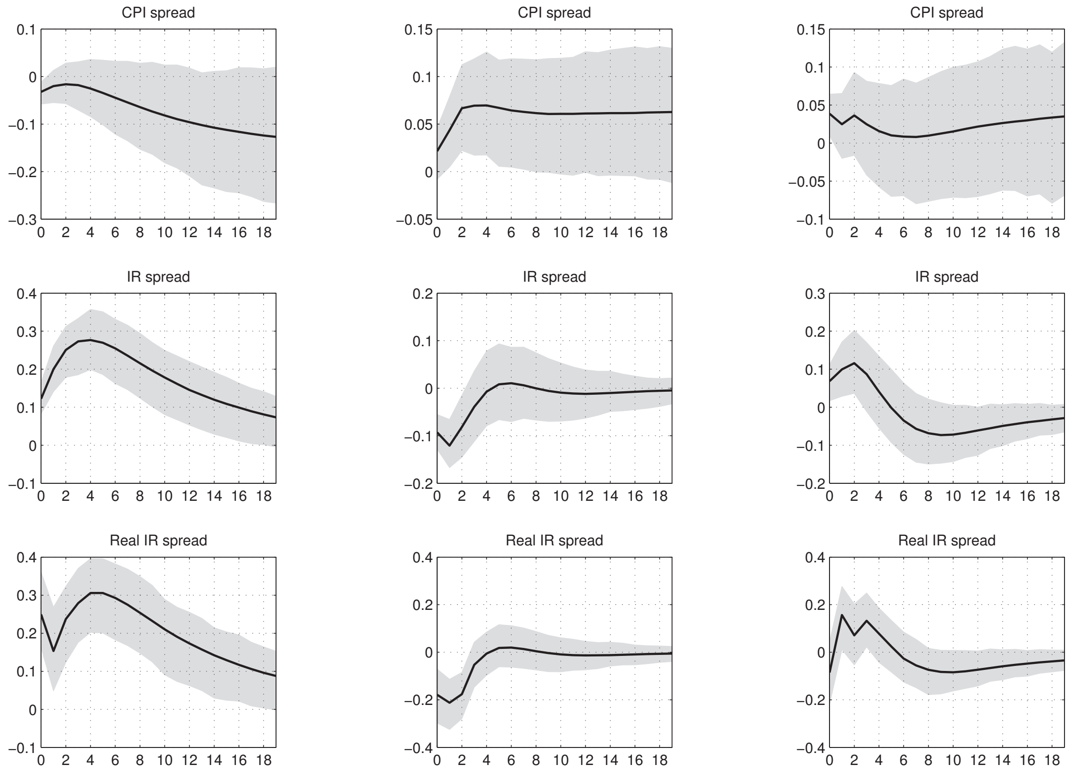
In light of the substantial positive impact of an expansionary monetary policy shock in the euro area on Swiss output, our results do not confirm that a beggar-thy-neighbor mechanism is at work. Liu et al. (2014) find similar results for the UK since the 1990s. This result suggests that the expenditure switching effect – where Swiss consumers increasingly buy imported instead of locally produced products as imports become relatively cheaper because of the Swiss franc appreciation – does not dominate. Indeed, import prices fall in contrast to the increase following a positive foreign demand shock, but the response remains limited (see Figure 10 in Appendix C). In particular, there is no clear evidence of relative price changes between domestic and imported goods in the long run.

Response to foreign cost-push shocks A cost-push shock in the euro area is associated with a rise in consumer prices together with a fall in output. This shock introduces a trade-off for most central banks. Even if price stability is the primary concern, central banks often also consider developments in the real economy for their decision-making.[8] On impact, the price response dominates and the central bank hikes interest rates to keep inflation under control. As time evolves, the adverse effects on output become more pronounced. Consequently, the central bank lowers policy rates again in order to fight the severe output contraction. The economic downturn in the euro area also has non-negligible effects on the Swiss economy. After a slight delay, Swiss output starts to fall significantly but less than in the euro area. Despite the 3M Euribor rising slightly stronger than the 3M Libor in the short term, the relative monetary policy stance remains fairly unchanged given that the real interest rate in Switzerland moves almost in step with that of the euro area. This may prevent the Swiss franc from depreciating more strongly. As a consequence, the response of Swiss consumer prices is comparable to the price response in the euro area (see Figure 4).

[8]The Swiss National Bank's mandate is described in the National Bank Act (Article 5, Paragraph 1): "[...] It shall ensure price stability. In so doing, it shall take due account of economic developments." The Lisbon Treaty (Article 127, Paragraph 1) states that "The primary objective of the European System of Central Banks [...] shall be to maintain price stability. Without prejudice to the objective of price stability, [the European System of Central Banks] shall support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union [...]." These objectives include "full employment" and "balanced economic growth".

Figure 4 – Impact of foreign inflationary shocks on spreads between Swiss and euro area CPI and interest rates

Positive Demand | Expansionary Monetary Policy | Cost-push



Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For the CPI spread, the cumulative responses are shown. The responses of the interest rate spreads along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. The responses of the CPI spread along the y-axis denote percentage changes. CPI spread: EA CPI minus Swiss CPI. IR spread: 3M Euribor minus 3M Libor. Real IR spread: Real 3M Euribor (3M Euribor minus EA CPI inflation) minus real 3M Libor (3M Libor minus Swiss CPI inflation).

Comparison of responses To summarize, all three foreign shocks result by construction in temporary higher inflation in the euro area. Likewise, these shocks are associated with temporary higher Swiss inflation. This is not surprising given the strong trade linkages between the euro area and Switzerland. Interestingly, however, the inflation differential between the euro area and Switzerland narrows in response to positive demand shocks, widens in response to expansionary monetary policy shocks and does not change significantly in response to cost-push shocks. The first shock is associated with a weaker Swiss franc, which slightly amplifies the pass-through of inflationary pressures from abroad. The second shock comes along with a stronger Swiss franc, shielding off some of the inflationary pressures from abroad. The third shock is associated with an exchange rate that hardly moves. These differences in exchange rate responses are plausibly driven by changes in the relative monetary policy stance. In addition, also note that the responses of the exchange rate and inflation abroad and in Switzerland to all three shocks are in line with the purchasing power theory, without imposing any restrictions on the joint behavior of these variables.

These results suggest that the magnitude of the spillover effects on Swiss prices depends crucially on the underlying forces driving foreign inflationary pressures and the associated monetary policy responses. Our findings are in line with recent evidence of Forbes et al. (2015), who document that the exchange rate pass-through is dependent on the nature of the shocks and may be a possible explanation for the ambiguous empirical evidence on the comovement of domestic and global inflation.

4.2 Foreign versus domestic inflationary pressures

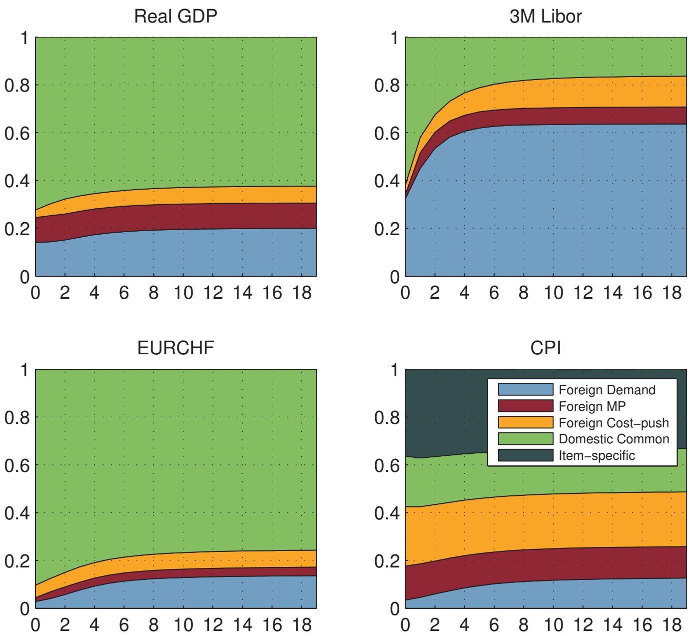
We show in the previous subsection that foreign inflationary shocks can have substantial spillover effects on the Swiss economy. An important question in this context is how important are spillover effects induced by foreign shocks relative to domestic forces? To answer this question and to obtain a better understanding of the relative importance of the different foreign shocks, we conduct a variance decomposition exercise.

Figure 5 shows the variance decomposition for the domestic common factors and the CPI constructed from the disaggregated price data. Depicted is the fraction of forecast error variance that is explained by the three identified foreign shocks as well as the (unidentified) domestic common and item-specific shocks at different horizons. It turns out that foreign shocks account for a substantial part of the variance of Swiss variables. In the medium run, they explain up to about 25% of the variation in the exchange rate, 40% of real GDP, 80% of the 3M Libor, and 50% of the CPI. In case of the CPI, the remaining part is explained by domestic common and item-specific shocks .[9] Approximately 30% of the variations in the CPI are explained by item-specific shocks, while domestic common shocks account for approximately 20%. The finding that approximately half of the variation of

[9]Recall that the CPI does not enter our system as an observable but is constructed from the disaggregated price data and thus features, in contrast to the other aggregates shown, an idiosyncratic part.

the Swiss CPI is driven by foreign shocks is in line with the findings of Jordan (2015). It is also in line with results for other (small) open economies (Aastveit et al. 2016).

Figure 5 – Variance decomposition of Swiss common factors and aggregate CPI

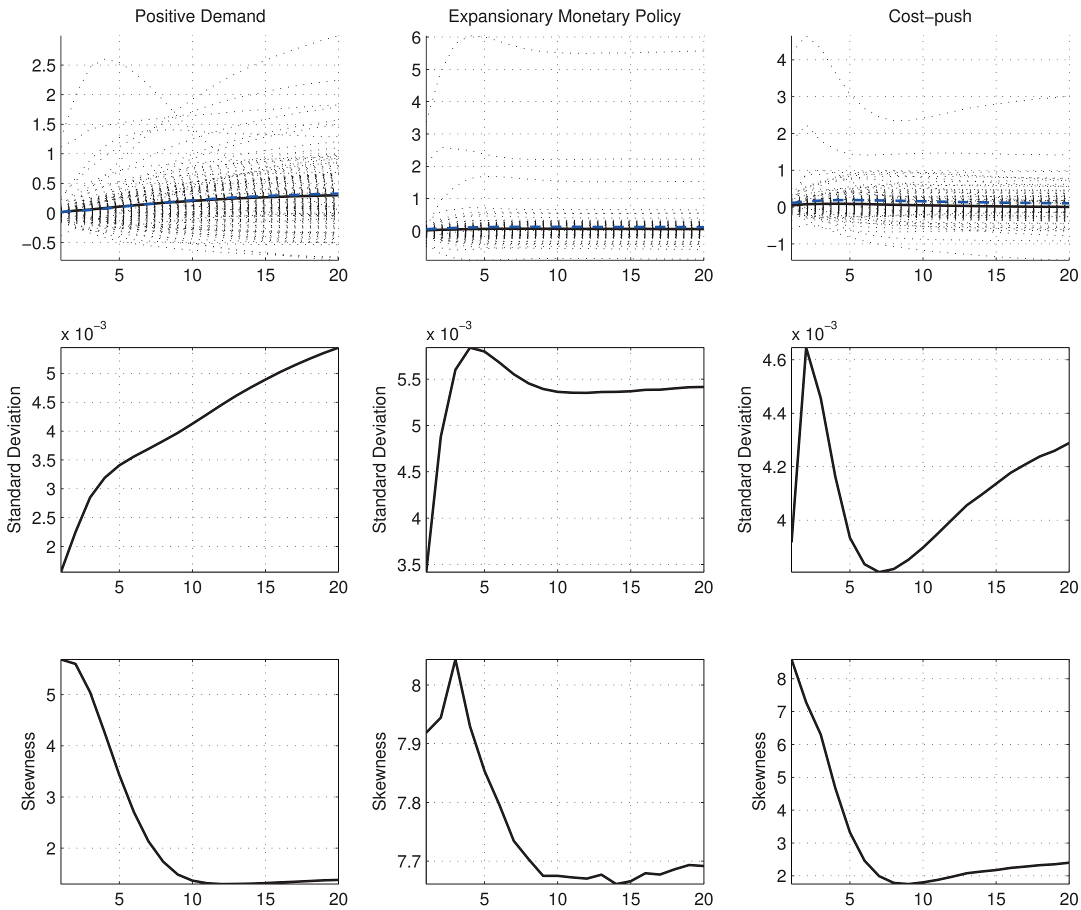


Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

The bulk of the foreign contribution to output, the interest rate as well as the exchange rate is due to foreign demand shocks. Monetary policy shocks generally account for a smaller fraction, which is a common finding in the literature and can be reconciled with the fact that this shock is thought to capture unsystematic variations in the policy stance, which should be small. Consumer prices turn out to be heavily driven by foreign cost-push shocks, particularly in the short run. At longer horizons, however, demand shocks become more important, whereas the contribution of foreign cost-push shock even slightly decreases. The variations in the relative importance of the different foreign shocks may point to some interesting heterogeneities in the transmission of foreign spillovers to Swiss prices.

By way of summary, our results indicate that international spillovers to the Swiss economy and to Swiss prices in particular are quantitatively important. Foreign demand shocks turn out to be an important driver of Swiss macroeconomic variables in general, and for Swiss prices, foreign cost-push shocks appear to be particularly important as well.

Figure 6 – Impact of foreign inflationary shocks on common factors on disaggregated prices



Note: The top panels of the figure illustrates the posterior median responses of the 148 CPI items for the three identified shocks at horizons up to 20 quarters (along the x-axis). The middle (bottom) panels show the standard deviation (skewness) of the responses across items for the three identified shocks at horizons up to 20 quarters (along the x-axis).

4.3 Heterogeneity in the transmission of spillovers

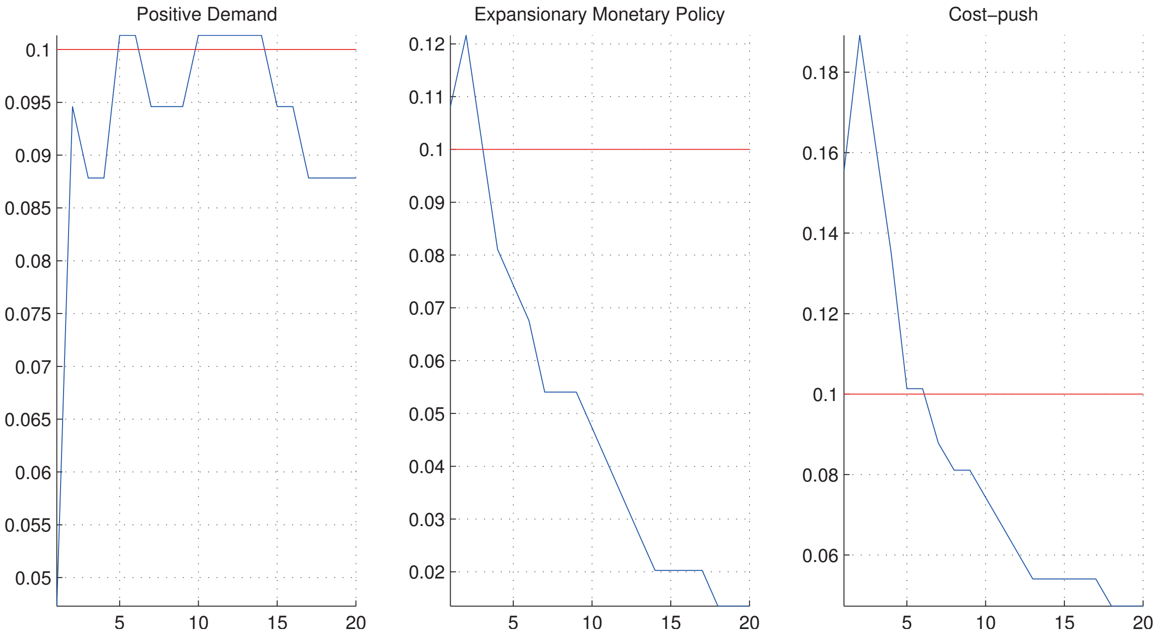
So far, we have focused our analysis on spillover effects at the aggregate level. However, our dynamic factor modeling framework allows us to study these effects at a highly disaggregate level as well, as it includes a vast number of disaggregated data on Swiss consumer prices. This may give valuable insights on item-specific differences and can shed light on how the aggregate effects are transmitted. Furthermore, the aggregation level of inflation is shown to influence the estimated degree of spillovers reported in studies such as Monacelli and Sala (2009).

In the top panels of Figure 6, we report the posterior median responses of the 148 CPI items for the three identified shocks. After a positive foreign demand shock, most prices increase persistently. However, some prices increase by a substantially smaller amount, while other prices even decrease – pointing to substantial heterogeneity. For the foreign monetary policy shock and the cost-push shock, both the heterogeneity in price responses and the fraction of items with increasing prices are smaller. The panels in the middle of Figure 6 show the standard deviation of the responses across items. All three shocks lead to a higher price dispersion, as can be seen by the higher standard deviation of the responses. Furthermore, the dispersion seems to be increasing with the forecast horizon. For the demand shock, the standard deviation increases gradually while the increase in dispersion materializes much faster in the case of a monetary policy shock. The pattern for the cost-push shock is slightly different with a substantial spike in the standard deviation of the responses in the first year after the shock, which seems to be driven by the responses of energy prices. In the bottom panels of Figure 6, we show that the distribution of price responses is positively skewed, particularly in the first 8-10 quarters. The increase in skewness indicates that foreign inflationary shocks transmit to the Swiss economy as shocks to relative prices. In line with Mumtaz and Surico (2009), we find a positive relationship between skewness and the aggregate price response, which is supportive of the fact that shocks to relative prices can be inflationary.

To take into account the uncertainty around these estimates, we follow Mumtaz and Surico (2009) and analyze for each item its distribution of relative price responses. For each item i and draw j, we compute the relative price response $\ln p_i^j - \ln \bar{p}^j$, where $\ln \bar{p}^j$ is the average (log) price response over all items for draw j. After having done this for all draws j, we compute for each item the fraction of relative price responses that are positive (across j), which we denote by α_i. By looking at the proportion of items for which $\alpha_i < 0.05$ or $\alpha_i > 0.95$ (i.e., items for which more than 95% of the responses decrease or increase, respectively, compared to the average response over all items), we can then evaluate whether the change in relative prices shows some statistical significance. If the share for which $\alpha_i < 0.05$ or $\alpha_i > 0.95$ is larger than 10%, we may conclude that the measured change in relative prices is not the result of estimation uncertainty.[10] Figure 7 shows the fraction of items for which $\alpha_i < 0.05$ or $\alpha_i > 0.95$. Our results

[10]Mumtaz and Surico (2009) interpret a fraction of responses above this threshold as significant, stating that 'one would typically expect 10% of the price responses to be significantly different from the average'.

Figure 7 – Fraction of items for which $\alpha < 0.05$ or $\alpha > 0.95$



Note: For each item i and draw j, we compute the relative price response $\ln p_i^j - \ln \bar{p}^j$, where $\ln \bar{p}^j$ is the average (log) price response over all items for draw j. After having done this for all draws j, we compute for each item the fraction of relative price responses that are positive (across j), which we denote by α_i. The figure shows for the three identified shocks the fraction of items for which $\alpha_i < 0.05$ or $\alpha_i > 0.95$.

for the foreign monetary policy shock and the cost-push shock are in line with Boivin et al. (2009) for domestic monetary policy shocks and Mumtaz and Surico (2009) for international supply shocks: in the short to medium run, there is evidence for significant relative price movements, as can be seen by the fact that the proportion of items for which $\alpha_i < 0.05$ or $\alpha_i > 0.95$ lies above 10% at horizons for up to one year. In the longer run, however, the responses converge to the average, as can be seen from the fact that the share of items that differ significantly from the average converges to zero. The results for the demand shock turn out to be quite different. While there seems to be no significant change in relative prices in the short run, there is evidence of significant relative price changes in the medium run, which slowly diminish towards the forecast horizon. This is consistent with the significant and persistent aggregate price response after a positive foreign demand shock.

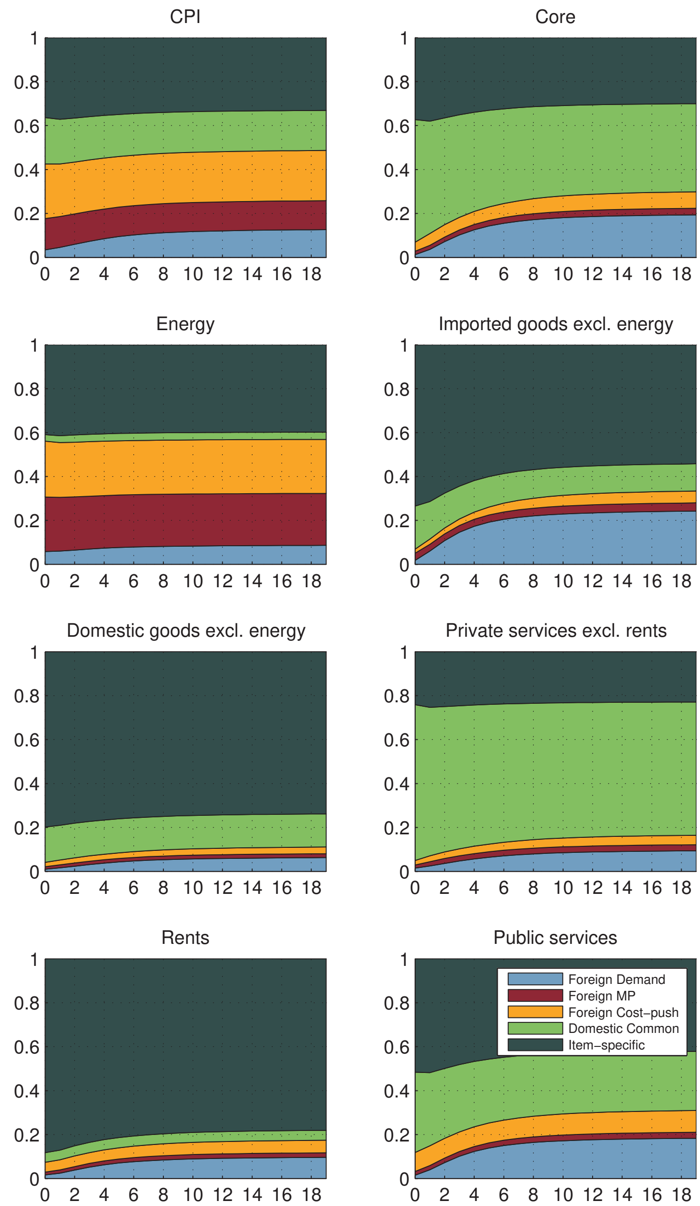
An analysis of a selection of different categories of the CPI reveals insights on the channels leading to the dispersed responses. Specifically, we look at core CPI, energy, imported goods excluding energy, domestic goods excluding energy, private services excluding rents, and public services. In defining the core measure, we follow the Swiss Federal Statistical Office (SFSO) and exclude fresh and seasonal items as well as energy. Moreover, we define all items with an average import share of above 50% over the sample period to be imported. Analogous to aggregate CPI, the statistics for these categories are computed based on the weights of the items. We focus here on the variance decomposition of the different categories; however, the corresponding impulse responses can be found in Figure 10 in Appendix C.[11] Figure 8 presents the variance decomposition for aggregate CPI and the selected price categories at different horizons.

The main results are threefold: first, the contribution of foreign shocks to core CPI is substantially lower when compared to the headline, particularly in the shorter term. It turns out that these differences are likely driven by energy prices. Energy prices are heavily affected by foreign shocks, and the transmission appears to occur quite fast as the foreign contribution stands at approximately 60% on impact and remains roughly at the same level afterwards. A large part of this contribution can be attributed to foreign cost-push shocks, which seems quite intuitive because these shocks likely reflect to a large extent unexpected changes in global energy prices (e.g., supply driven oil price shocks). The strong and direct impact of foreign cost-push shocks on energy prices appears to be transmitted to headline CPI, for which cost-push shocks also explain a dominant share, particularly in the shorter term. In contrast, the major part of the foreign contribution in core CPI, which does not include energy prices, is due to demand shocks, whereas cost-push shocks explain considerably less.

Second, there are some interesting heterogeneities in the relative importance of foreign shocks, which are likely related to differences in tradability and exchange rate sensitivity of the respective price categories. For categories featuring a high tradability such as energy and imported goods (excluding energy), foreign shocks explain a large share of the price variations. In contrast, foreign shocks account for a smaller fraction of categories that are less tradable, such as domestic goods (excluding energy) and services, while domestic

[11] Note that we calculate the decomposition for the particular indices, which are obtained by aggregating the items included in the categories of interest. Because of this, however, our results are not directly comparable to those of Monacelli and Sala (2009), who use a simple average of the decompositions for the single items in a given category. In Appendix D, we discuss the role of the aggregation in more detail.

Figure 8 – Variance decomposition of different categories of Swiss consumer prices



Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

common shocks turn out to be relatively more important. Still, foreign shocks explain some of the variation in service inflation. This result is in line with the findings of Hałka and Szafranek (2016) for the Czech Republic, Poland and Sweden.

Third, rents feature a dominant item-specific component, whereas common shocks turn out to be less important. This may reflect the fact that in Switzerland, rents are tied to mortgage rates by law and therefore behave very differently than other prices.

To summarize, our empirical findings suggest that significant differences exist between different price categories. It turns out that energy prices seem to play an important role in the transmission of international spillovers. Indeed, foreign shocks explain a markedly lower share of consumer prices when energy prices are excluded. This finding is in line with recent empirical evidence presented in other studies. Parker et al. (2016) documents that global factors are particularly important in explaining energy prices, and Hałka and Kotłowski (2016) conclude that commodity-specific shocks are an important source of inflation variability in the Czech Republic, Poland and Sweden. Altansukh et al. (2017) argue that in a low inflation environment such as the one analyzed in this paper, the volatility of energy inflation has become relatively more important for explaining short-run changes in headline inflation.

4.4 Robustness

We check the robustness of our results along a number of dimensions, including the specification of the foreign model block, the model dimensions, data de-trending, and the sample period. The results are shown in Appendix E.

To address the first issue, we replace the euro area block of the model with a global block consisting of export-weighted indicators of Switzerland's most important trading partners.[12] The results based on the global factors are in line with the results based on the factors for the euro area (see Figures 11 and 12). Consequently, our findings seem to not only pertain to spillovers emerging from the euro area but to international inflation spillovers to Switzerland more generally.

[12]In particular, we use export-weighted real GDP as a measure of foreign demand, an export-weighted CPI as a measure of foreign CPI, an export-weighted policy rate of the US, euro area, and Japan as a measure of the foreign policy stance, and the nominal effective exchange rate (NEER) as the relevant exchange rate index. A positive exchange rate change implies an appreciation of the Swiss franc as in the benchmark analysis with the EURCHF.

The sensitivity analysis with respect to the number of unobserved factors suggests that more than one unobserved factor leads to some instability in the estimates, probably due to the further increased number of estimated parameters. Having said that, the model with two unobserved factors mirrors the impulse responses of that with one unobserved factor, but suggests that international spillovers may affect Swiss inflation of imported items (excluding energy) and domestic goods more strongly (see Figures 13 and 14).

Our findings are also robust to the choice of the lag number. Figures 15 and 16 show the results with the lag order in the state and the observation equations of $p = 1$ and $q = 0$ (note that there is a contemporaneous impact), respectively. Figures 17 and 18 show the results with the lag order in the state and the observation equations of $p = 3$ and $q = 2$, respectively.

We also checked the sensitivity to the prior tightness. We find that the results are robust to a change in the prior parameters from $\pi_1 = \pi_2 = \pi_3 = 1$ to $\pi_1 = 0.2, \pi_2 = 0.7, \pi_3 = 2$ (which is in the region used by Karlsson (2013) in his forecasting exercise). Given the increased prior tightness, we allow for four lags in the state equation. Figures 19 and 20 show the results. The most noticeable difference is that the exchange rate response to a foreign demand shock becomes somewhat weaker, but the sign remains the same such that our conclusions are still supported.

Some of the (nominal) variables exhibit a slight downward trend in the first part of the sample. Therefore, we check the robustness of our conclusions to estimates with all variables de-trended using the Hodrick-Prescott filter. From the results shown in Figures 21 and 22, we can conclude that our findings are robust to this modification of the data. However, the impulse responses of Swiss GDP and CPI to foreign demand and cost-push shocks are somewhat more volatile than in the benchmark estimation.

Our results also appear to be fairly robust to the choice of the sample period. To ensure that the impact of the financial crisis and the Great Recession does not drive our main results, we estimate the model with data until 2007Q4. We find that the main results do not change with one exception (see Figures 23 and 24). The Swiss franc does not depreciate in response to a positive foreign demand shock. We even see a tendency of an appreciation. In line with the exchange rate response, the spillover effects through imported inflation to Swiss CPI inflation is more muted in the shorter sample. At the same time, the increase in the interest rate differential between the Euribor and the 3M Libor is somewhat smaller in the shorter sample. This might reflect that the 3M Libor was close to zero in 2010 and 2011. As a result, after the onset of the financial crisis, Swiss monetary policy might have been limited to some extent in counteracting negative foreign demand shocks with its interest rate instrument. Indeed, Bäurle and Kaufmann (2014) find that the response of the trade weighted CHF exchange rate to risk shocks becomes more pronounced at the effective lower bound for nominal interest rates (ELB). Thus, our result that the relative interest rate reaction is influenced by the ELB periods and the exchange rate reaction changes supports their result. Furthermore, it supports our conclusion that monetary policy influences the spillover of shocks. Still, the result that the Swiss franc even appreciates in the sample excluding the financial crisis and the Great Recession remains somewhat puzzling. The estimated change in the interest rate differential seems to be too small quantitatively for the exchange rate response to change its sign. Moreover, in real terms, the interest rate differential even diminishes once the crisis period is removed from the sample. However, the appreciation disappears when we replace the euro area with a broader measure for the foreign economy as described above, with the other responses remaining very similar (this result is not shown but can be obtained by the authors) such that we do not want to over-emphasize this result.

4.5 Implications for monetary policy

In the previous subsections, we have shown that Swiss CPI inflation is to a substantial degree driven by foreign factors. However, this does not imply that Swiss inflation escapes the control of national monetary policy for two reasons.

Firstly, recall that a considerable part of the impact of foreign factors on aggregate CPI is driven by energy prices. However, these effects fade over time, and therefore, monetary policy does routinely look through (supply induced) changes in energy prices. For example, Atukeren (2003) does not find considerable second-round effects of oil price movements on Swiss core inflation.

Secondly, and most importantly, we show that spillover effects depend crucially on the nature of the underlying shocks and the associated monetary policy responses and related exchange rate movements. Thus, our results suggest that Swiss monetary policy has been able to affect international spillover effects on domestic inflation. However, the Swiss National Bank has taken foreign factors into account in fulfilling its mandate, which is reflected by the high explanatory power of foreign shocks for variations in the 3M Libor. Our findings can be reconciled with the theoretical model developed by Woodford (2007): as long as exchange rates adjust flexibly to changes in economic conditions, central banks' ability to control inflation is unlikely to be threatened by global integration of markets per se. However, the way an economy behaves is influenced by its degree of openness, which must be taken into account by monetary policy.

5 Conclusion

In this paper, we analyze how different shocks driving up the euro area's CPI inflation translate into inflationary pressures in Switzerland, putting particular emphasis on the relative monetary policy responses and the corresponding exchange rate fluctuations. Based on a structural dynamic factor model relating a large set of disaggregated Swiss consumer prices to key foreign and domestic factors, we study how foreign inflationary shocks are transmitted to Swiss prices. We identify three different types of inflationary shocks that are widely discussed in the literature: a positive demand shock, an expansionary monetary policy, and a cost-push shock, all originating abroad.

We find that foreign shocks explain up to approximately 50% of Swiss price variations, while common domestic shocks account for only approximately 20% (with the remaining part being due to item-specific shocks). Thus, domestic inflation is to a substantial degree driven by foreign shocks. However, this does not imply that Swiss monetary policy has not been able to affect international spillover effects to domestic inflation. Indeed, spillover effects on Swiss prices are crucially dependent on the nature of the underlying shock and the associated monetary policy responses. Following an increase in inflation in the euro area due to a positive demand shock, euro area monetary policy counteracts the business cycle upturn strongly, while the Swiss monetary policy reaction turns out to be less restrictive. As a result of the change in the relative monetary policy stance, the Swiss franc depreciates and inflation picks up even somewhat more than in the euro area. In contrast, in response to an increase in inflation in the euro area due to an expansionary monetary policy shock, monetary policy becomes relatively tighter in Switzerland. As a result, the Swiss franc appreciates, mitigating spillover effects to Swiss inflation. Finally, a cost-push shock driving up inflation (and decreasing real activity) in the euro area has only little effects on the relative monetary policy stance, particularly when considering real interest rates. As a consequence, the effects on the exchange rate turn out to be negligible, and the increase in Swiss inflation is comparable to that of euro area inflation.

These results indicate that spillover effects need to be analyzed in a framework allowing for different transmission channels: an increase in inflation abroad may affect the inflation in an open economy differently, depending on the source of the foreign shock, and thus, movements in other factors such as interest and exchange rates. This may also partly explain the ambiguity of the empirical evidence on the impact of spillovers found so far.

The analysis of the different items of the Swiss CPI points to substantial heterogeneities in the transmission of international spillovers. It turns out that energy prices play a crucial role in the transmission, particularly in the short run. The impact of foreign inflationary shocks on Swiss CPI is lower, and the transmission appears to be slower when energy prices are excluded. Furthermore, there is some heterogeneity in the transmission to the prices of goods and services, which may likely be explained by differences in tradability and exchange rate sensitivity. This further underpins the importance of the relative stance of monetary policy through its effect on the exchange rate.

We conclude that although international spillovers are substantial, the relative stance of monetary policy between two currency areas is an important determinant of their magnitude. In that sense, independent monetary policy does, at least to some extent, shield against international spillovers.

References

Aastveit, K. A., H. C. Bjørnland, and L. A. Thorsrud (2016): "The world is not enough! Small open economies and regional dependence," *The Scandinavian Journal of Economics*, 118, 168–195.

Altansukh, G., R. Becker, G. Bratsiotis, and D. R. Osborn (2017): "What is the Globalisation of Inflation?" *Journal of Economic Dynamics and Control*, 74, 1–27.

Anderson, B. D. O. and J. B. Moore (1979): *Optimal Filtering*, Prentice Hall.

Arias, J. E., J. F. Rubio-Ramírez, and D. F. Waggoner (2014): "Inference Based on SVARs Identified with Sign and Zero Restrictions: Theory and Applications," Tech. rep., Federal Reserve Bank of Atlanta.

Atukeren, E. (2003): "Oil prices and the Swiss economy," Working Paper 77, KOF Swiss Economic Institute, ETH Zurich.

Auer, R., C. E. Borio, and A. J. Filardo (2017a): "The Globalisation of Inflation: the Growing Importance of Global Value Chains," Working Paper 602, Bank for International Settlements.

Auer, R. A., A. A. Levchenko, and P. Saure (2017b): "International Inflation Spillovers Through Input Linkages," Working Paper 2017-03, Swiss National Bank.

Baumeister, C. and L. Benati (2013): "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound," *International Journal of Central Banking*, 9, 165–212.

Bäurle, G. (2013): "Structural Dynamic Factor Analysis Using Prior Information From Macroeconomic Theory," *Journal of Business and Economic Statistics*, 31, 136–150.

Bäurle, G. and D. Kaufmann (2014): "Exchange rate and price dynamics in a small open economy - the role of the zero lower bound and monetary policy regimes," Working Papers 2014-10, Swiss National Bank.

Bäurle, G. and E. Steiner (2015): "How do individual sectors respond to macroeconomic shocks? A structural dynamic factor approach applied to Swiss data," *Swiss Journal of Economics and Statistics (SJES)*, 151, 167–225.

Bauwens, L., M. Lubrano, and J.-F. Richard (1999): *Bayesian Inference in Dynamic Econometric Models*, Oxford University Press.

Boivin, J. and M. Giannoni (2006): "DSGE Models in a Data-Rich Environment," NBER Technical Working Paper 0332, National Bureau of Economic Research, Inc.

BOIVIN, J., M. P. GIANNONI, AND I. MIHOV (2009): "Sticky prices and monetary policy: Evidence from disaggregated US data," *The American Economic Review*, 99, 350–384.

CANOVA, F. (2005): "The transmission of US shocks to Latin America," *Journal of Applied Econometrics*, 20, 229–251.

CARRIERO, A., T. CLARK, AND M. MARCELLINO (2014): "No Arbitrage Priors, Drifting Volatilities, and the Term Structure of Interest Rates," CEPR Discussion Papers 9848, C.E.P.R. Discussion Papers.

CARTER, C. K. AND P. KOHN (1994): "On Gibbs Sampling for State Space Models," *Biometrica*, 81, 541–553.

CHIB, S. (1993): "Bayes regression with autoregressive errors : A Gibbs sampling approach," *Journal of Econometrics*, 58, 275–294.

CICCARELLI, M. AND B. MOJON (2010): "Global inflation," *The Review of Economics and Statistics*, 92, 524–535.

FORBES, K. J., I. M. HJORTSOE, AND T. NENOVA (2015): "The Shocks Matter: Improving Our Estimates of Exchange Rate Pass-Through," External MPC Unit Discussion Papers 43, External MPC Unit, Bank of England.

FRÜHWIRTH-SCHNATTER, S. (1994): "Data augmentation in dynamic linear models," *Journal of Time Series Analysis*, 15, 183–202.

GEORGIADIS, G. (2016): "Determinants of global spillovers from US monetary policy," *Journal of International Money and Finance*, 67, 41–61.

GEWEKE, J. (1992): "Bayesian Statistics," in *Bayesian Statistics*, ed. by J. Bernardo, J. Berger, A. Dawid, and A. Smith, Oxford University Press,, vol. 4.

——— (2005): *Contemporary Bayesian Econometrics and Statistics*, John Wiley & Sons, Inc.

HAŁKA, A. AND J. KOTŁOWSKI (2016): "Global or domestic? Which shocks drive inflation in European small open economies?" *Emerging Markets Finance and Trade*, forthcoming.

Hałka, A. and K. Szafranek (2016): "Whose Inflation Is It Anyway? Inflation Spillovers Between the Euro Area and Small Open Economies," *Eastern European Economics*, 54, 109–132.

Jordan, T. J. (2015): "The Impact of International Spillovers on Inflation Dynamics and Independent Monetary Policy: the Swiss Experience," Jackson Hole Conference Paper, Swiss National Bank.

Karlsson, S. (2013): "Forecasting with Bayesian Vector Autoregressions," in *Handbook of Economic Forecasting*, ed. by G. Elliott and A. Timmermann, Elsevier Amsterdam, vol. 2, chap. 15, 791–897.

Kim, C.-J. and C. R. Nelson (1999): *State-Space Models with Regime Switching*, The MIT Press.

Kim, S. (2001): "International transmission of US monetary policy shocks: Evidence from VAR's," *Journal of Monetary Economics*, 48, 339–372.

Liu, P., H. Mumtaz, and A. Theophilopoulou (2014): "The transmission of international shocks to the UK. Estimates based on a time-varying factor augmented VAR," *Journal of International Money and Finance*, 46, 1–15.

Maćkowiak, B. (2007): "External shocks, US monetary policy and macroeconomic fluctuations in emerging markets," *Journal of Monetary Economics*, 54, 2512–2520.

Monacelli, T. and L. Sala (2009): "The international dimension of inflation: evidence from disaggregated consumer price data," *Journal of Money, Credit and Banking*, 41, 101–120.

Mumtaz, H. and P. Surico (2009): "The transmission of international shocks: a factor-augmented VAR approach," *Journal of Money, Credit and Banking*, 41, 71–100.

——— (2012): "Evolving International Inflation Dynamics: World and Country-specific Factors," *Journal of the European Economic Association*, 10, 716–734.

Neely, C. J. and D. E. Rapach (2011): "International comovements in inflation rates and country characteristics," *Journal of International Money and Finance*, 30, 1471–1490.

NEUSSER, K. (2009): *Zeitreihenanalyse in den Wirtschaftwissenschaften*, Vieweg + Teubner Verlag, 3rd ed.

PARKER, M. ET AL. (2016): "Global inflation: the role of food, housing and energy prices," Tech. rep., Reserve Bank of New Zealand.

POIRIER, D. (1998): "Revising Beliefs in Nonidentified Models," *Econometric Theory*, 14, 483–509.

POTJAGAILO, G. (2017): "Spillover effects from Euro area monetary policy across Europe: A factor-augmented VAR approach," *Journal of International Money and Finance*, 72, 127–147.

PRIMICERI, G. E. (2005): "Time Varying Structural Vector Autoregressions and Monetary Policy," *Review of Economic Studies*, 72, 821–52.

RIETH, M. (2015): "Can central banks successfully lean against global headwinds?" DIW Roundup 88, Deutsches Institut für Wirtschaftsforschung.

UHLIG, H. (2005): "What are the effects of monetary policy on output? Results from an agnostic identification procedure," *Journal of Monetary Economics*, 52, 381–419.

WOODFORD, M. (2007): "Globalization and Monetary Control," NBER Working Paper 13329, National Bureau of Economic Research.

A Disaggregated price data

For the disaggregated price data, we rely on micro data at the consumer item level collected by the Swiss Federal Statistical Office (SFSO). It is important to note that the number of consumer items may change over time due to revisions of the CPI. To obtain a homogenous dataset, we group the data into 148 CPI items accounting for the major Swiss CPI revisions. The dataset accounts for approximately 99% of the CPI on average because certain items, for which we were unable to find an appropriate group, are excluded from the panel. The resulting CPI items are seasonally and calendar adjusted, and items featuring collection frequencies lower than a quarter are interpolated. Figure 9 shows the historical evolution of aggregate CPI inflation together with the inflation series of the 148 CPI items (both calculated as qoq rates). There is a substantial degree of heterogeneity among different CPI items. Furthermore, inflation rates of single items turn out to be more volatile and generally less persistent than aggregate CPI inflation. These observations are confirmed by looking at the standard deviations and the AR(1) coefficients of aggregate CPI inflation and different price categories as shown in Table 2 and are in line with evidence of Boivin et al. (2009) on the United States.

Figure 9 – Aggregate and disaggregated inflation series (qoq)

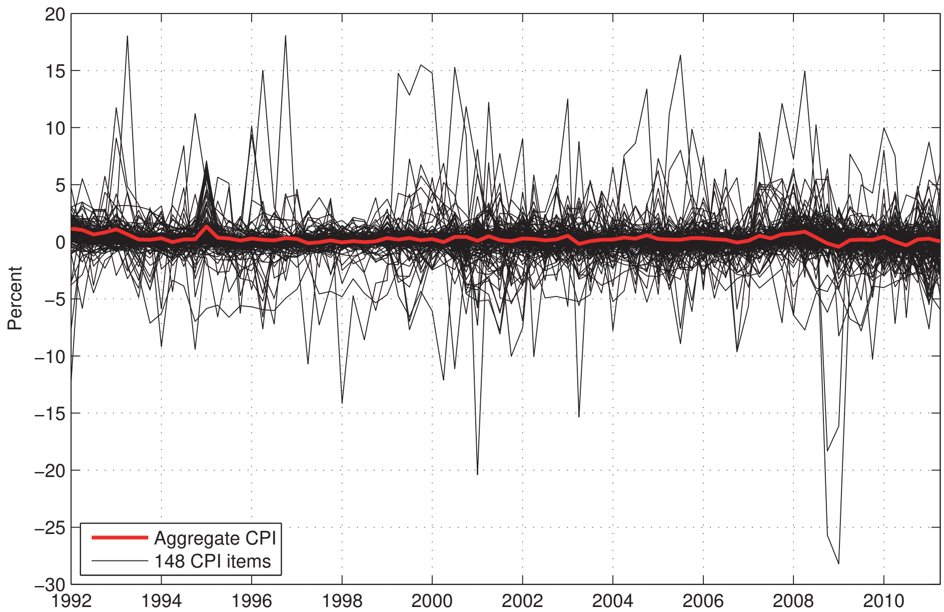


Table 2 – Volatility and persistence of inflation series (qoq)

Category	**Std. deviation**				**Persistence**			
	Mean	5th	50th	95th	Mean	5th	50th	95th
Aggregate CPI	0.31				0.45			
Categories								
CPI (148)	1.10	0.40	0.83	2.46	0.29	−0.16	0.30	0.64
Core (131)	0.94	0.40	0.77	1.91	0.29	−0.16	0.30	0.64
Energy (4)	4.64	1.21	4.08	9.22	0.27	0.10	0.25	0.48
Imported goods excl. energy (65)	0.98	0.38	0.84	2.02	0.36	0.01	0.40	0.66
Domestic goods excl. energy (46)	1.16	0.47	0.92	2.97	0.15	−0.24	0.20	0.55
Private services excl. rents (28)	0.73	0.28	0.69	1.27	0.36	0.06	0.35	0.80
Rents (1)	0.43	0.43	0.43	0.43	0.56	0.56	0.56	0.56
Public services (5)	1.23	0.68	1.21	1.76	0.17	−0.03	0.18	0.44

Note: The table shows the volatility and persistence of aggregate CPI inflation and inflation rates of different CPI categories (number of items in the categories are depicted in brackets). Volatility and persistence of each category are calculated as the unweighted average of the item-specific volatilities and persistence measures of those items included in the respective category. The persistence of the series is measured by the estimated first-order autoregressive coefficient.

B Detailed model description and estimation method

In this section, we provide a description of the estimation method. As the posterior distribution cannot be derived analytically, we use Markov Chain Monte Carlo (MCMC) methods to simulate from the posterior distribution. In our setting, this can be done using a Gibbs sampling approach (see, e.g., Kim and Nelson (1999) with one iteration of the Gibbs sampler involving the following steps:

Step 1: Draw the factors conditional on a set of model parameters

Step 2: Draw parameters in the observation equation conditional on the factors

Step 3: Draw parameters in the state equation conditional on the factors

Iterating over these steps delivers draws from the posterior distribution of the parameters and the factors. Subsequently, we provide a detailed description of the three steps including the specification of the prior distribution.

Step 1: Drawing the factors To draw from the joint distribution of the factors given the parameter in the model, we use the algorithm of Carter and Kohn (1994) and Frühwirth-Schnatter (1994). The algorithm uses a Kalman filter. In our setting, the filter has to be adapted for autoregressive errors and potentially co-linear states, see, e.g., Anderson and Moore (1979) and Kim and Nelson (1999).

Step 2: Drawing parameters in the observation equation We use an informative prior on the factor loadings as this 'identifies' the factors in the sense that it puts curvature into the posterior density function for regions in which the likelihood function is flat, see, e.g., discussion in Bäurle (2013). In our implementation, the prior is centered such that, a priori, the series are all related with loading one to the unobserved factors contemporaneously and with loading zero to the lagged factors. However, the variance of the prior is chosen to be large, such that if the data are informative about the loadings, this will be reflected in the posterior distribution.

Regarding the parametric form of the prior, we use the specification of the conjugate prior described in Bauwens et al. (1999), p.58: The prior distribution $p(R_n, \Lambda_n \mid \Psi_n)$, where n denotes the respective row in the observation equation, is of the normal-inverted gamma-2 form (as defined in the appendix of Bauwens et al. (1999)):

$$R_n \sim \mathrm{iG}_2(s, \nu)$$

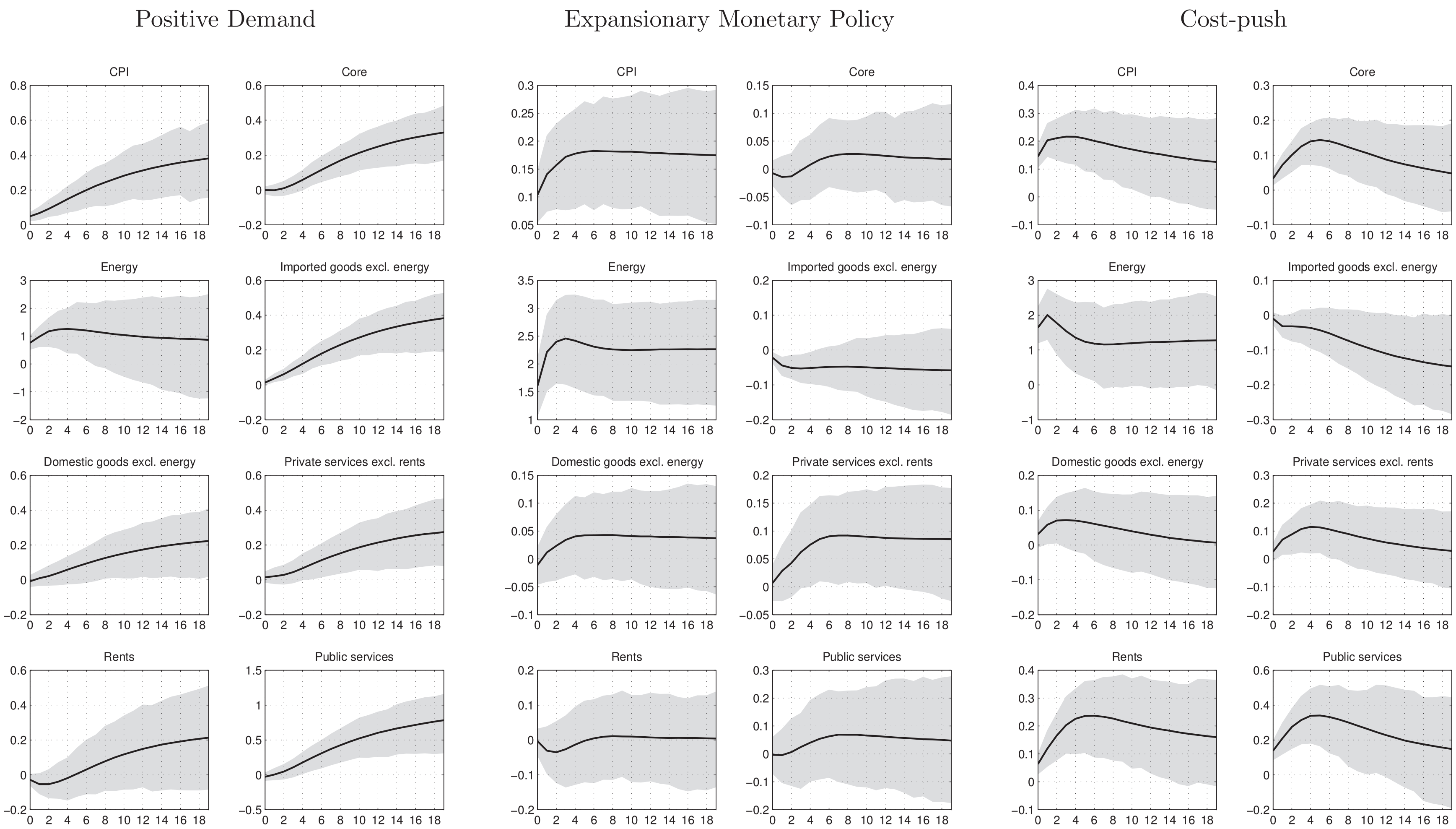
$$\Lambda_n \sim \mathrm{N}(\Lambda_{0,n}, R_n M_{0,n}^{-1})$$

Λ_0 is the prior mean of the distribution. The parameters s and ν parameterize the distribution of the variance of the measurement error. M_0 is a matrix of parameters that influences the tightness of the priors in the observation equation. The larger the elements of M_0 are, the closer we relate the observed series to the factors a priori. The choice of the tightness is determined by the a priori confidence in the prior belief. We set $M_{0,n,\varrho} = \varrho^2$ for all n and $\varrho = 1, \ldots, q$. Thus, the tightness of the prior increases quadratically with the lag of the factor. Following Boivin and Giannoni (2006), we set $s = 3$ and $\nu = 0.001$. By adding a standard normal prior for Ψ_n, we have specified a complete prior distribution for the parameters in the observation equation. The derivation of the posterior distribution is standard, see, e.g., Chib (1993) and Bauwens et al. (1999).

Step 3: Drawing parameters in the state equation We implement a normal Wishart prior for the parameters in the state equation. The prior mean and variances are of a "Minnesota-type", following Karlsson (2013). We set the hyper-parameter as follows. In Karlsson (2013)'s notation, we use $\pi_1 = \pi_2 = \pi_3 = 1$ to implement a very loose prior and set the prior mean of the first own lag to zero as we model stationary series. The prior is conjugate, i.e., the conditional densities $p(\Sigma|F,\Phi)$ and $p(\Phi|F,\Sigma)$ can be shown to be multivariate normal and inverse Wishart densities, respectively (see Bauwens et al. (1999) or Karlsson (2013)). Hence, we introduce this additional Gibbs-sampling step into our MCMC algorithm.

C Spillovers to different price categories

Figure 10 – Impact of foreign inflationary shocks on different price categories



Note: The figure illustrates the cumulative impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. The responses along the y-axis denote percentage changes.

D The role of aggregation in the variance decomposition

As outlined in the main body of the paper, we compute the variance decompositions of the different price categories for the particular indices and not as the average of the decomposition for the items in a given category. Intuitively, one would expect that the item-specific part in the decomposition for the index is smaller than in the average of the decomposition for the different items in the category. This is because by aggregating the items of a category to an index, some of the item-specific variations might cancel out. In contrast, the average of the variance decomposition for the different items in a category still reflects all item-specific variation. In this sense, the foreign contributions to domestic inflation reported in Monacelli and Sala (2009) can be thought of as a lower bound.

This is confirmed by our results. Table 3 shows the variance decomposition for the indices and the (weighted) average of the decomposition for the components in the categories at different horizons. One sees that the item-specific part is much larger for the weighted averages than for the indices, particularly in the short run. Conversely, common factors, both domestic and foreign, explain a larger share for the indices. Thus, when interpreting the contribution of common factors, one should bear in mind that the higher the level of aggregation is, the higher the contribution of common factors and the smaller the item-specific part.

Table 3 – Variance decomposition for the indices and (weighted) average of variance decompositions for the items in the different categories at different horizons.

$h = 0$	Index					Weighted Average				
Sector/Shock	D	MP	CP	Dom	Idio	D	MP	CP	Dom	Idio
Swiss CPI	0.03	0.14	0.25	0.21	0.36	0.02	0.02	0.04	0.14	0.78
Core	0.01	0.02	0.04	0.56	0.37	0.02	0.02	0.03	0.14	0.80
Energy	0.06	0.25	0.25	0.03	0.41	0.03	0.11	0.11	0.15	0.59
Imported goods excl. energy	0.02	0.03	0.02	0.20	0.73	0.02	0.02	0.02	0.07	0.87
Domestic goods excl. energy	0.01	0.01	0.02	0.16	0.80	0.02	0.02	0.03	0.10	0.83
Private services excl. rents	0.02	0.01	0.02	0.71	0.24	0.01	0.02	0.02	0.30	0.65
Rents	0.02	0.01	0.04	0.04	0.88	0.02	0.01	0.04	0.04	0.88
Public services	0.02	0.02	0.09	0.37	0.52	0.01	0.01	0.06	0.19	0.72

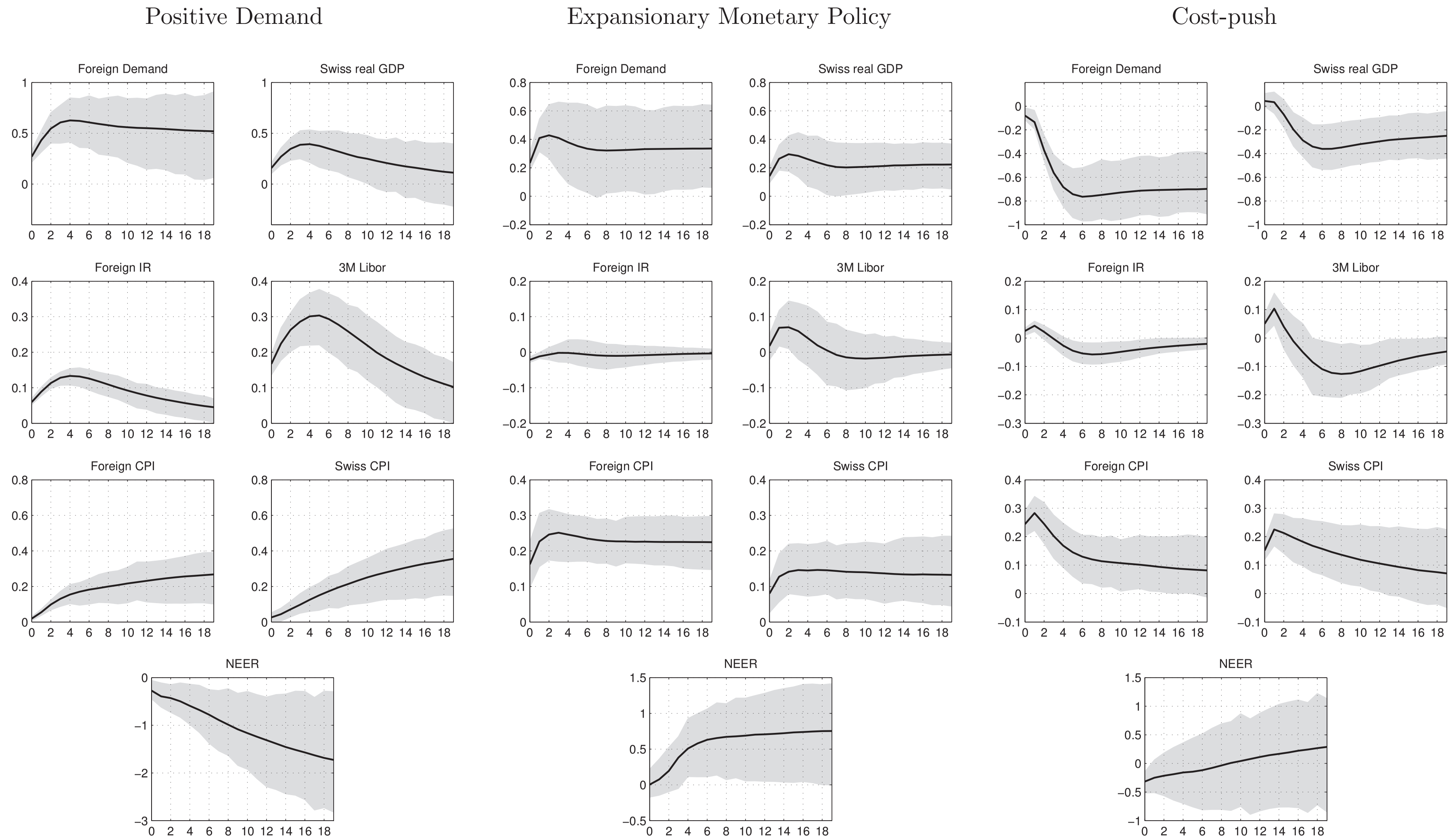
$h = 4$	Index					Weighted Average				
Sector/Shock	D	MP	CP	Dom	Idio	D	MP	CP	Dom	Idio
Swiss CPI	0.09	0.13	0.23	0.19	0.35	0.06	0.03	0.04	0.13	0.73
Core	0.13	0.02	0.06	0.45	0.34	0.06	0.02	0.04	0.14	0.74
Energy	0.07	0.24	0.25	0.03	0.41	0.05	0.11	0.11	0.14	0.58
Imported goods excl. energy	0.17	0.03	0.03	0.14	0.62	0.06	0.02	0.03	0.06	0.83
Domestic goods excl. energy	0.04	0.02	0.03	0.16	0.77	0.05	0.02	0.03	0.10	0.80
Private services excl. rents	0.06	0.02	0.03	0.64	0.24	0.07	0.02	0.03	0.29	0.59
Rents	0.06	0.02	0.05	0.05	0.82	0.06	0.02	0.05	0.05	0.82
Public services	0.12	0.02	0.09	0.30	0.47	0.11	0.02	0.06	0.17	0.64

$h = 16$	Index					Weighted Average				
Sector/Shock	D	MP	CP	Dom	Idio	D	MP	CP	Dom	Idio
Swiss CPI	0.12	0.13	0.23	0.18	0.33	0.09	0.03	0.05	0.13	0.70
Core	0.19	0.03	0.07	0.40	0.30	0.10	0.02	0.04	0.13	0.71
Energy	0.09	0.24	0.25	0.03	0.40	0.07	0.11	0.11	0.14	0.56
Imported goods excl. energy	0.24	0.04	0.05	0.12	0.54	0.09	0.02	0.03	0.06	0.79
Domestic goods excl. energy	0.06	0.02	0.03	0.15	0.74	0.07	0.02	0.04	0.10	0.77
Private services excl. rents	0.09	0.03	0.04	0.61	0.23	0.10	0.03	0.04	0.28	0.56
Rents	0.10	0.02	0.06	0.04	0.78	0.10	0.02	0.06	0.04	0.78
Public services	0.18	0.03	0.10	0.27	0.42	0.15	0.02	0.07	0.16	0.59

Note: The weights used in the calculations of the average are based on the CPI weights.

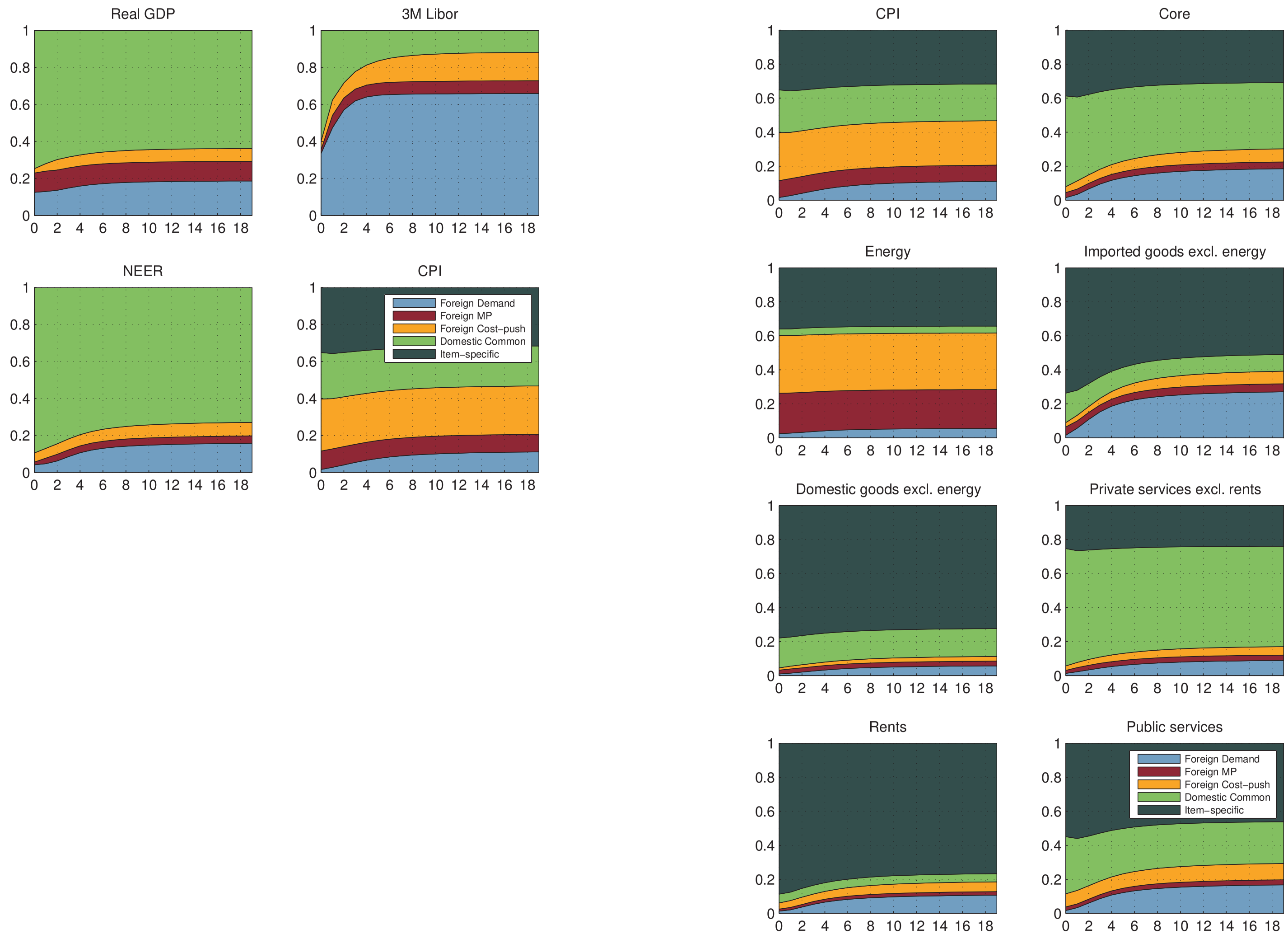
E Robustness analyses

Figure 11 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI for the model with world block



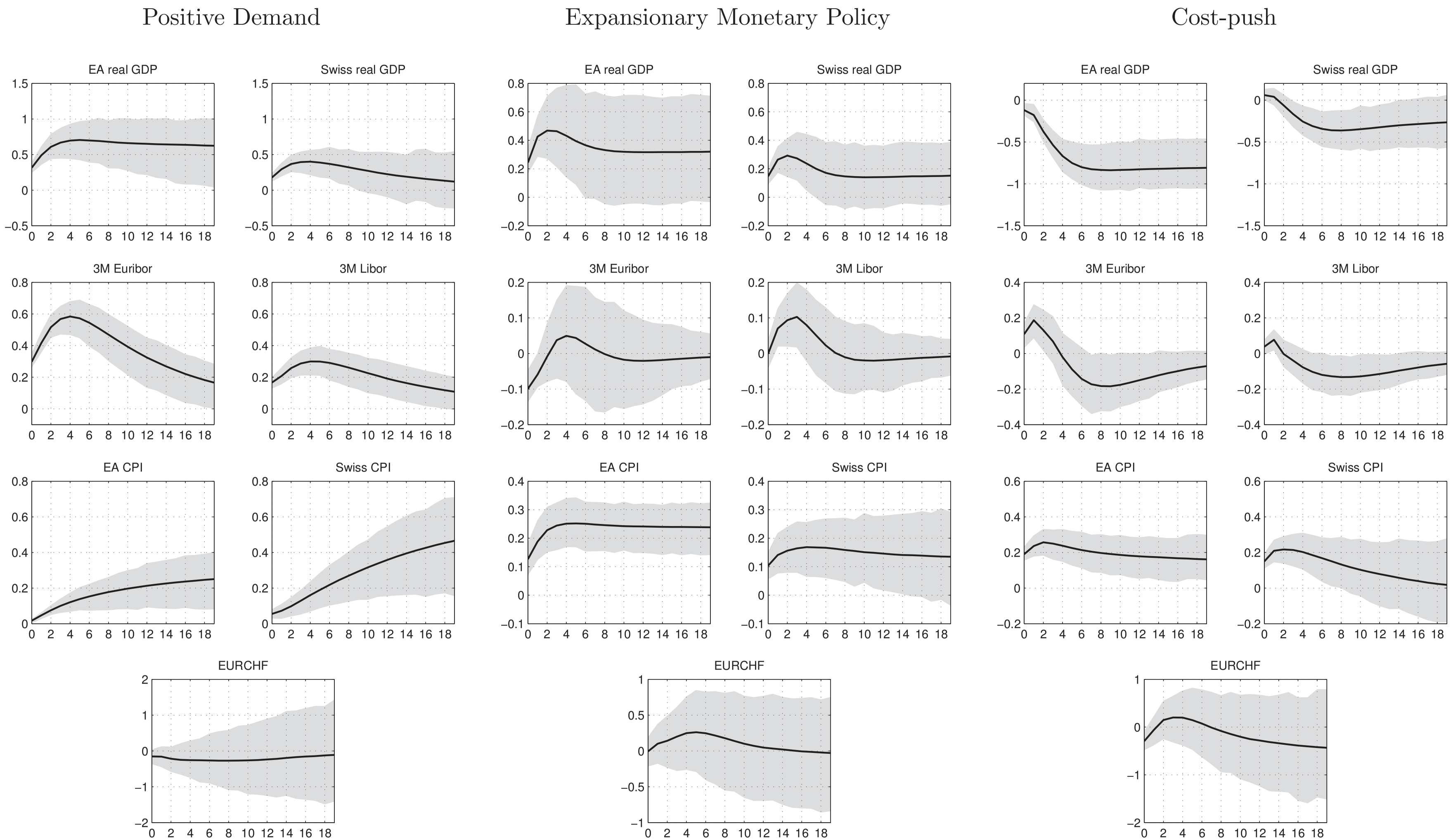
Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The response of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. All other responses along the y-axis denote percentage changes.

Figure 12 – Variance decomposition of Swiss variables and different price categories for the model with world block



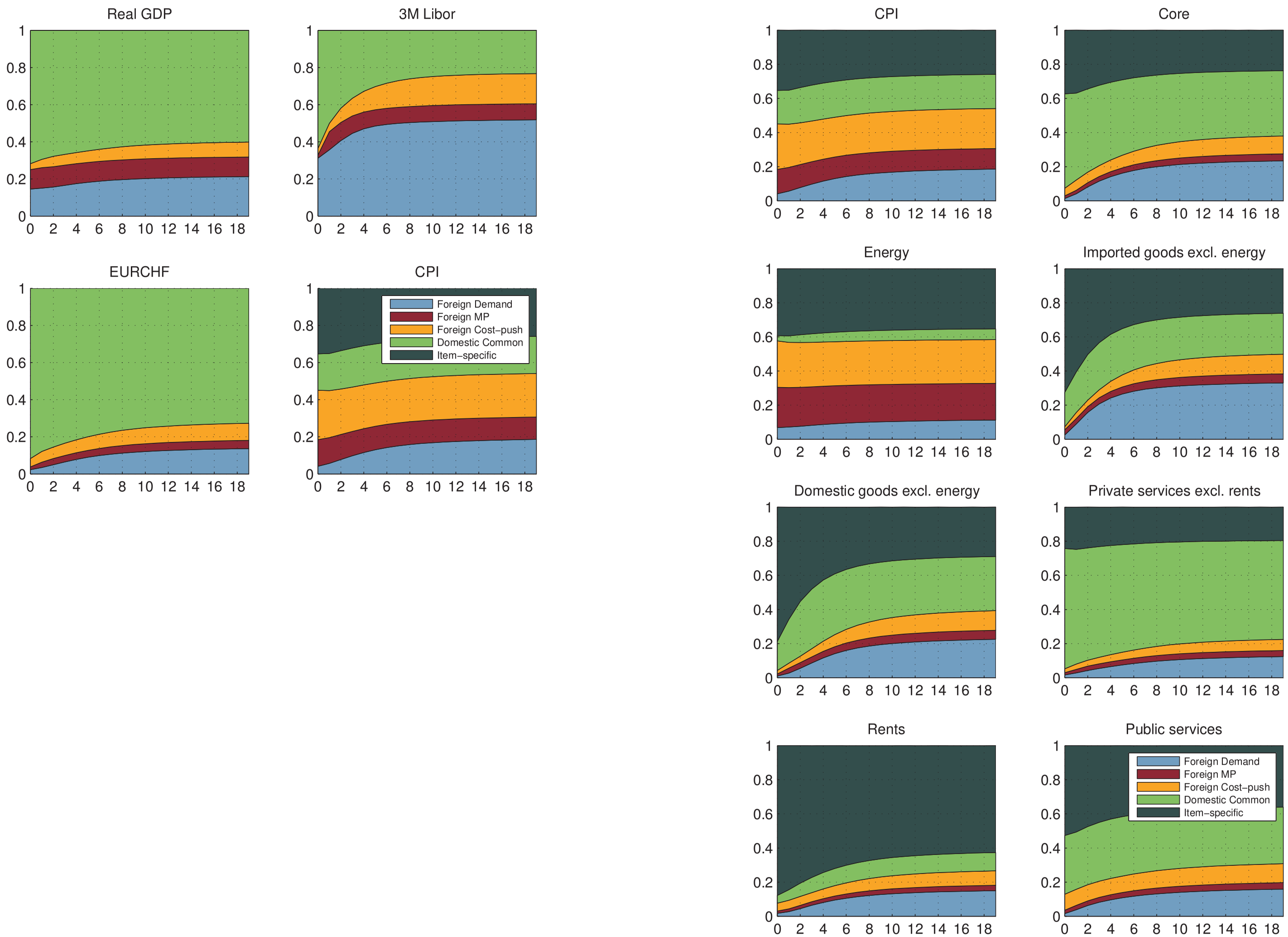
Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

Figure 13 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI for the model with 2 unobserved factors



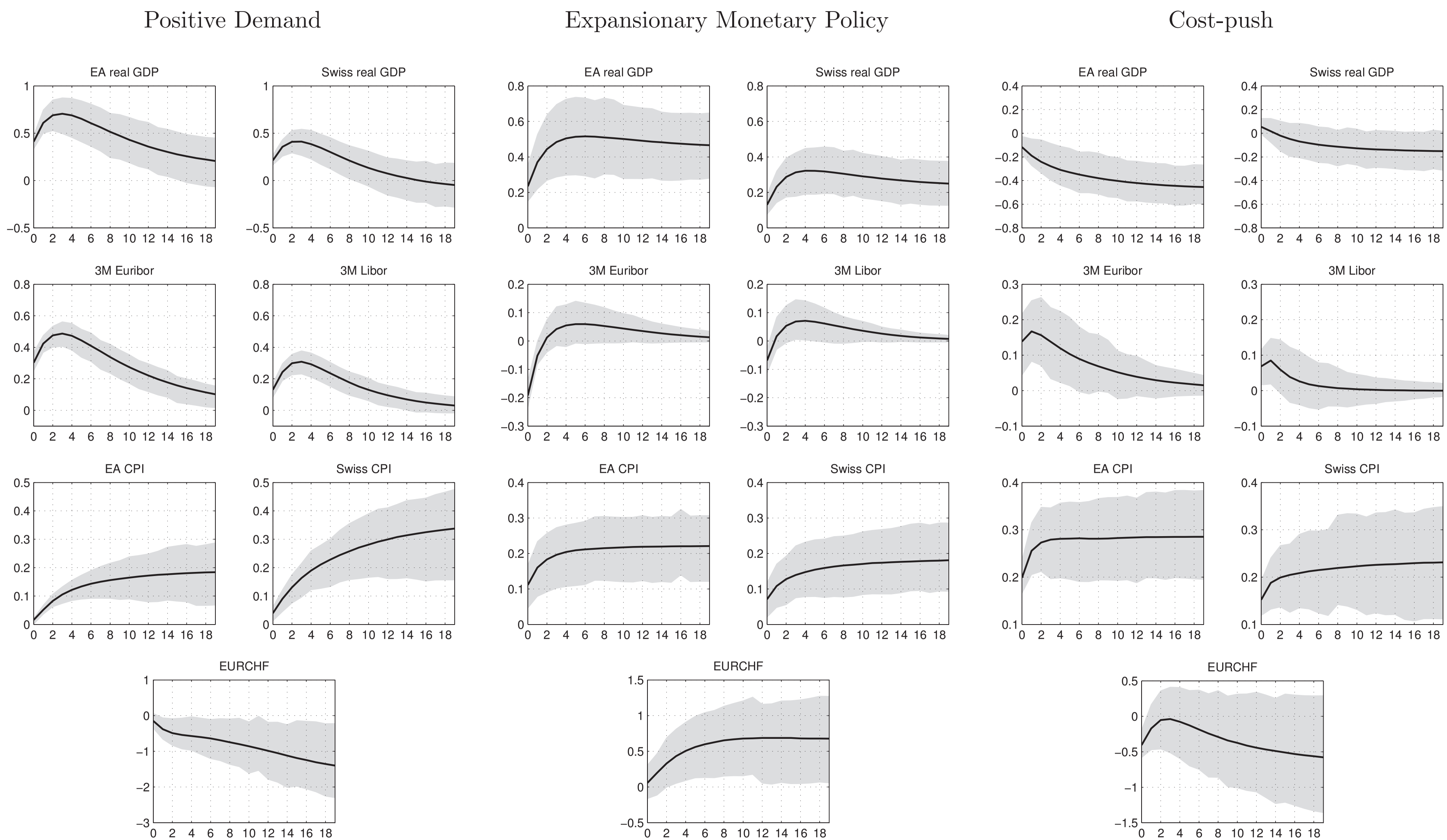
Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The response of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. All other responses along the y-axis denote percentage changes.

Figure 14 – Variance decomposition of Swiss variables and different price categories for the model with 2 unobserved factors



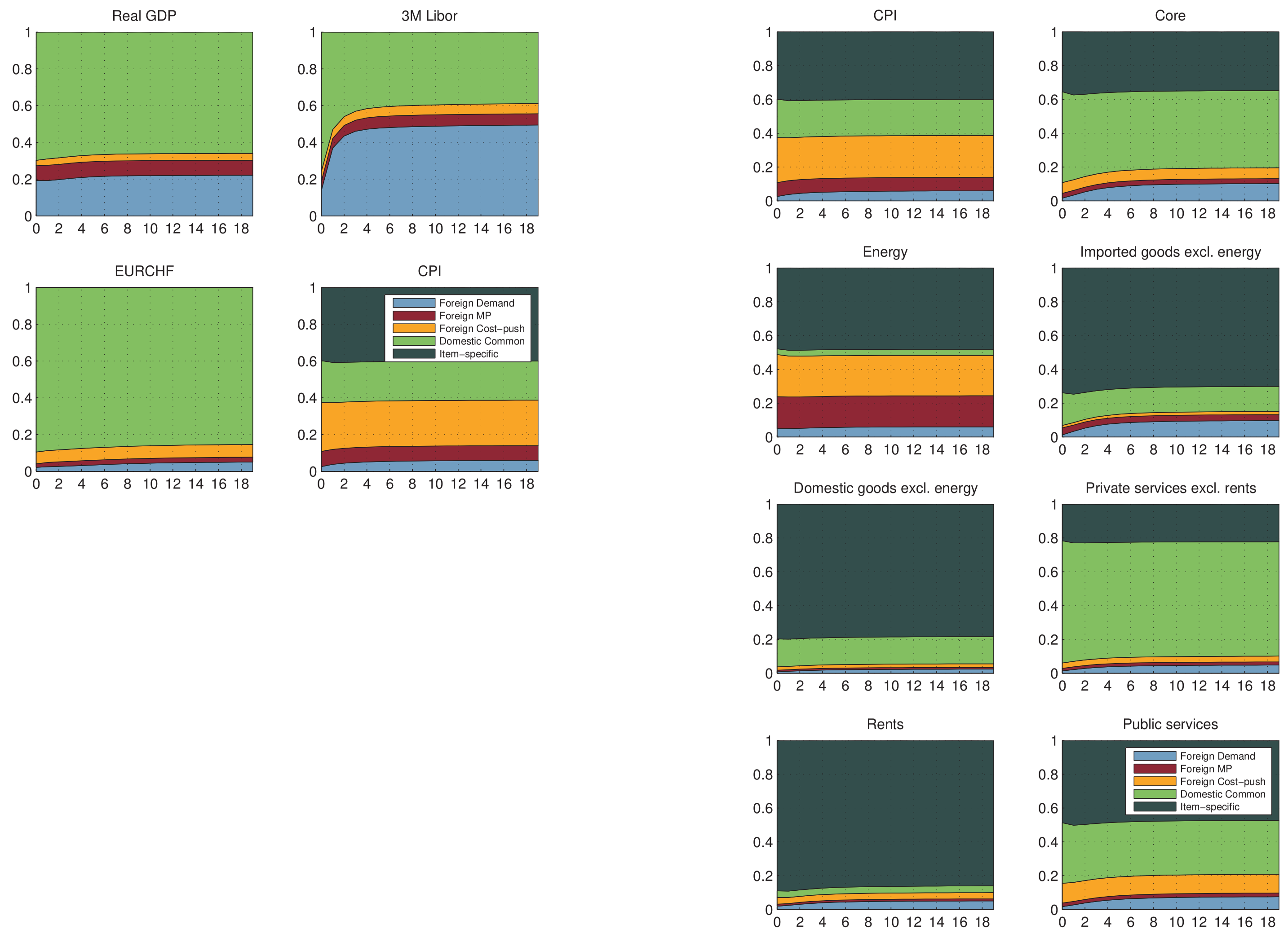
Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

Figure 15 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI for the model with 1 lag in the state equation and 0 lags in the observation equation



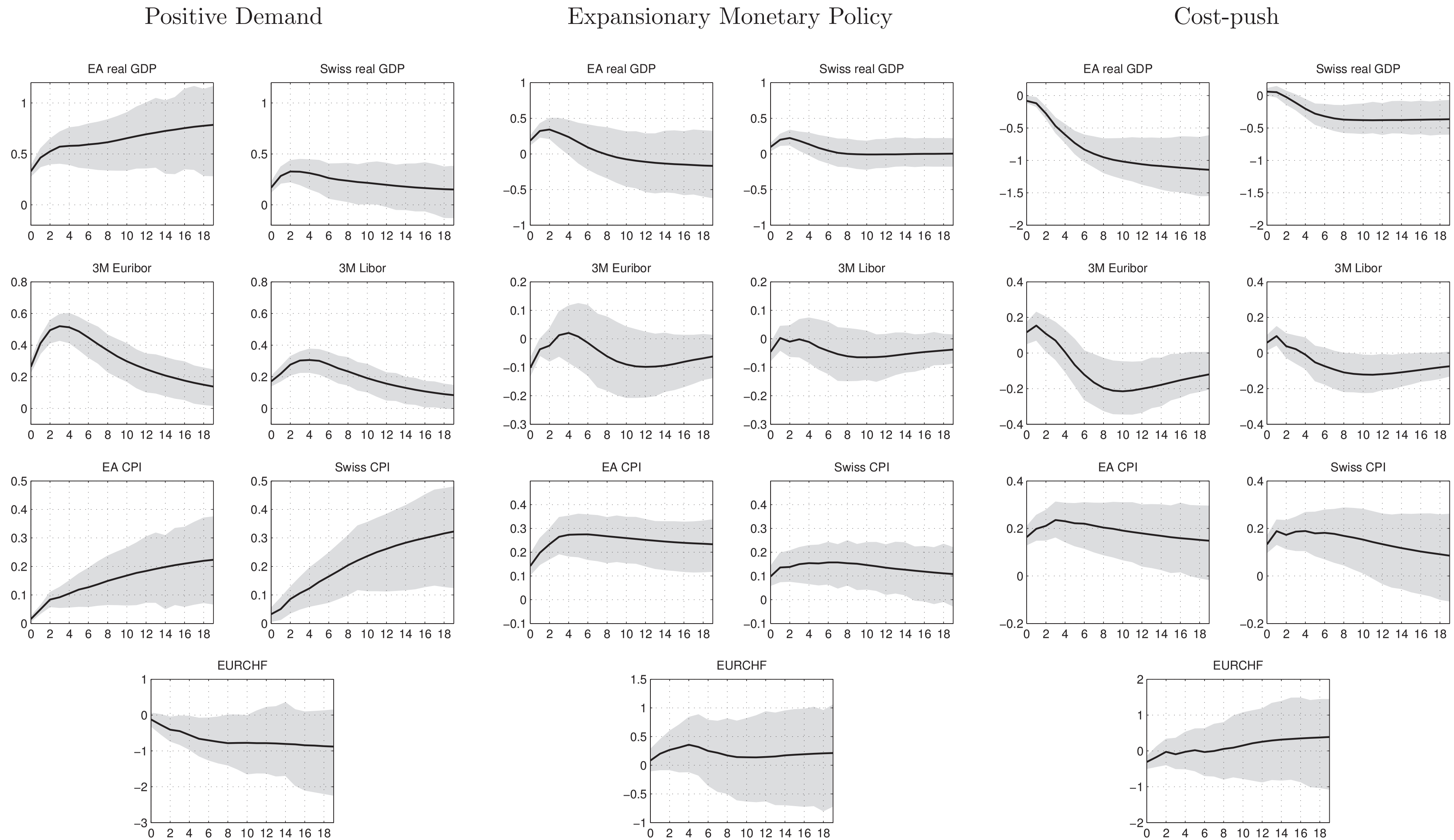
Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The response of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. All other responses along the y-axis denote percentage changes.

Figure 16 – Variance decomposition of Swiss variables and different price categories for the model with 1 lag in the state equation and 0 lags in the observation equation



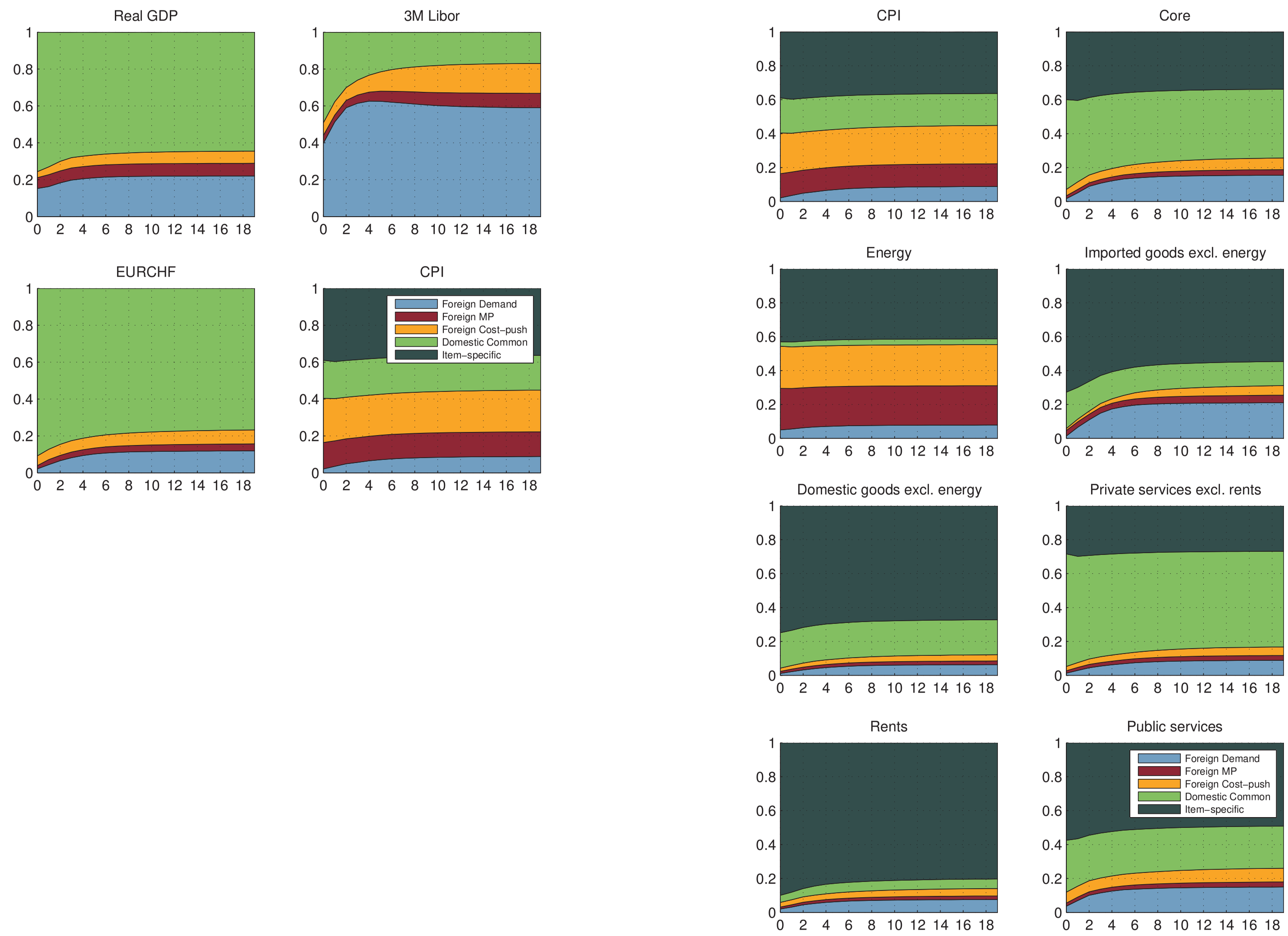
Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

Figure 17 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI for the model with 3 lags in the state equation and 2 lags in the observation equation



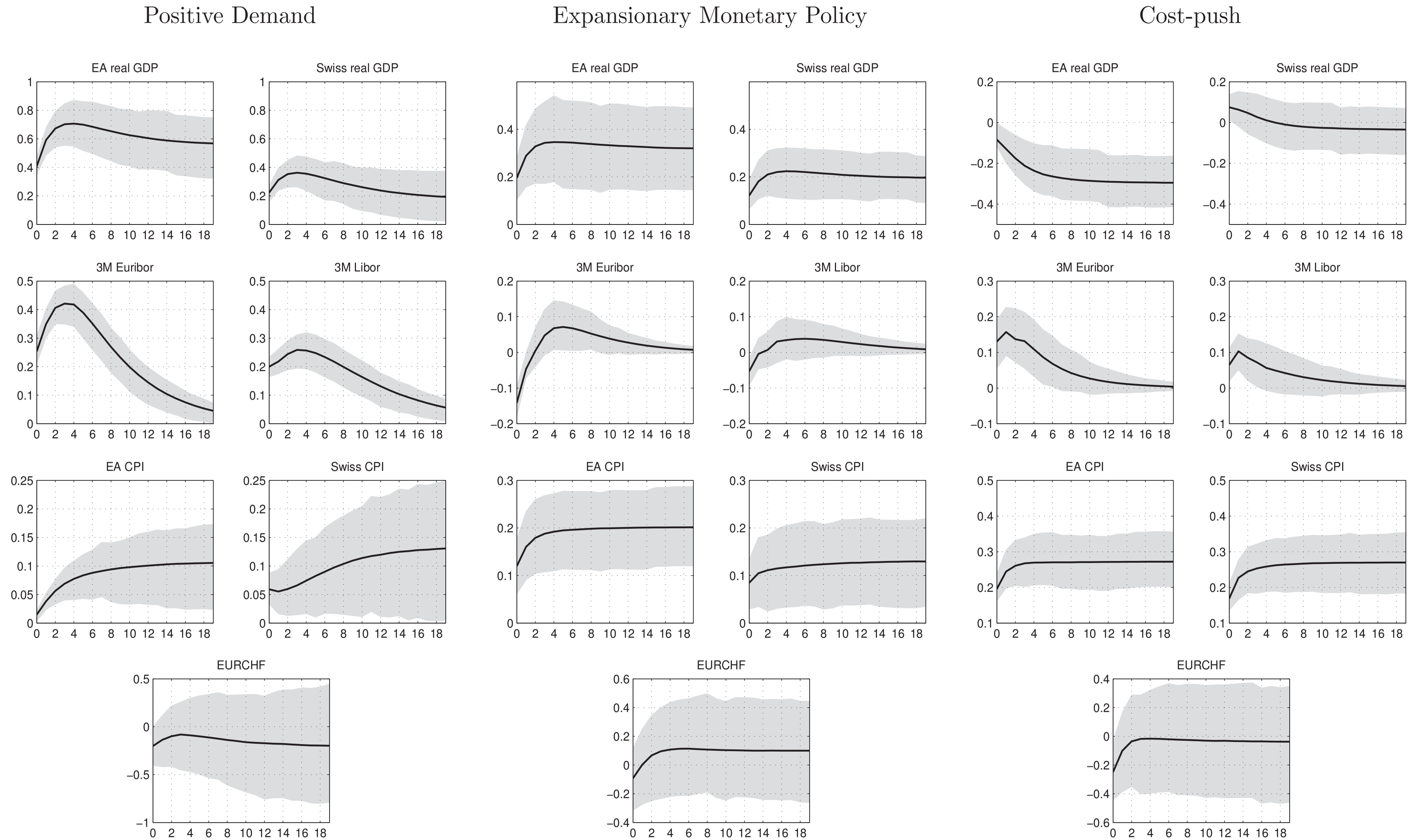
Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The response of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. All other responses along the y-axis denote percentage changes.

Figure 18 – Variance decomposition of Swiss variables and different price categories for the model with 3 lags in the state equation and 2 lags in the observation equation



Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

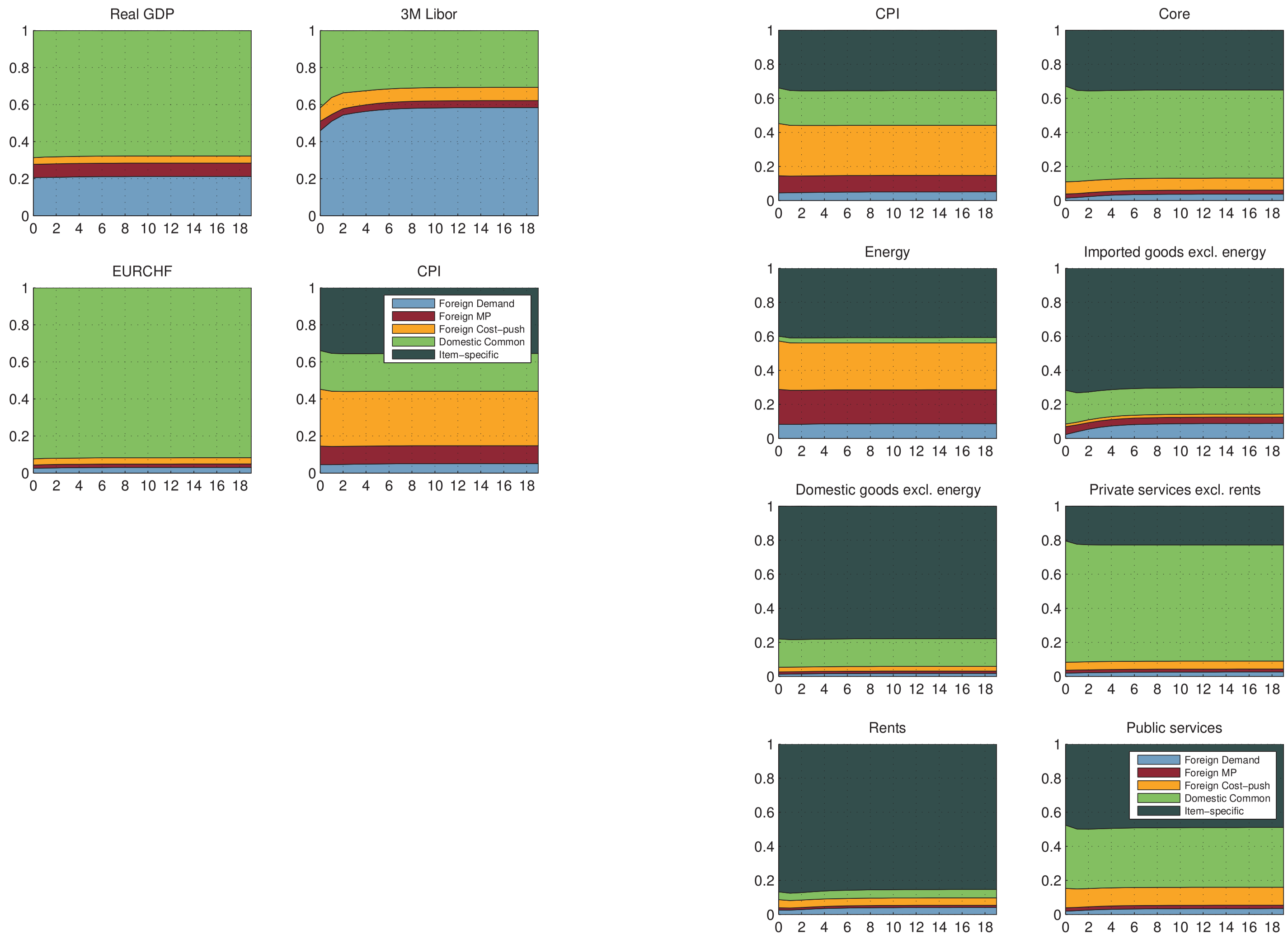
Figure 19 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI for the model with prior parameters $\pi_1 = 0.2, \pi_2 = 0.7, \pi_3 = 2$ and 4 lags in the state equation and 1 lag in the observation equation



Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The response of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. All other responses along the y-axis denote percentage changes.

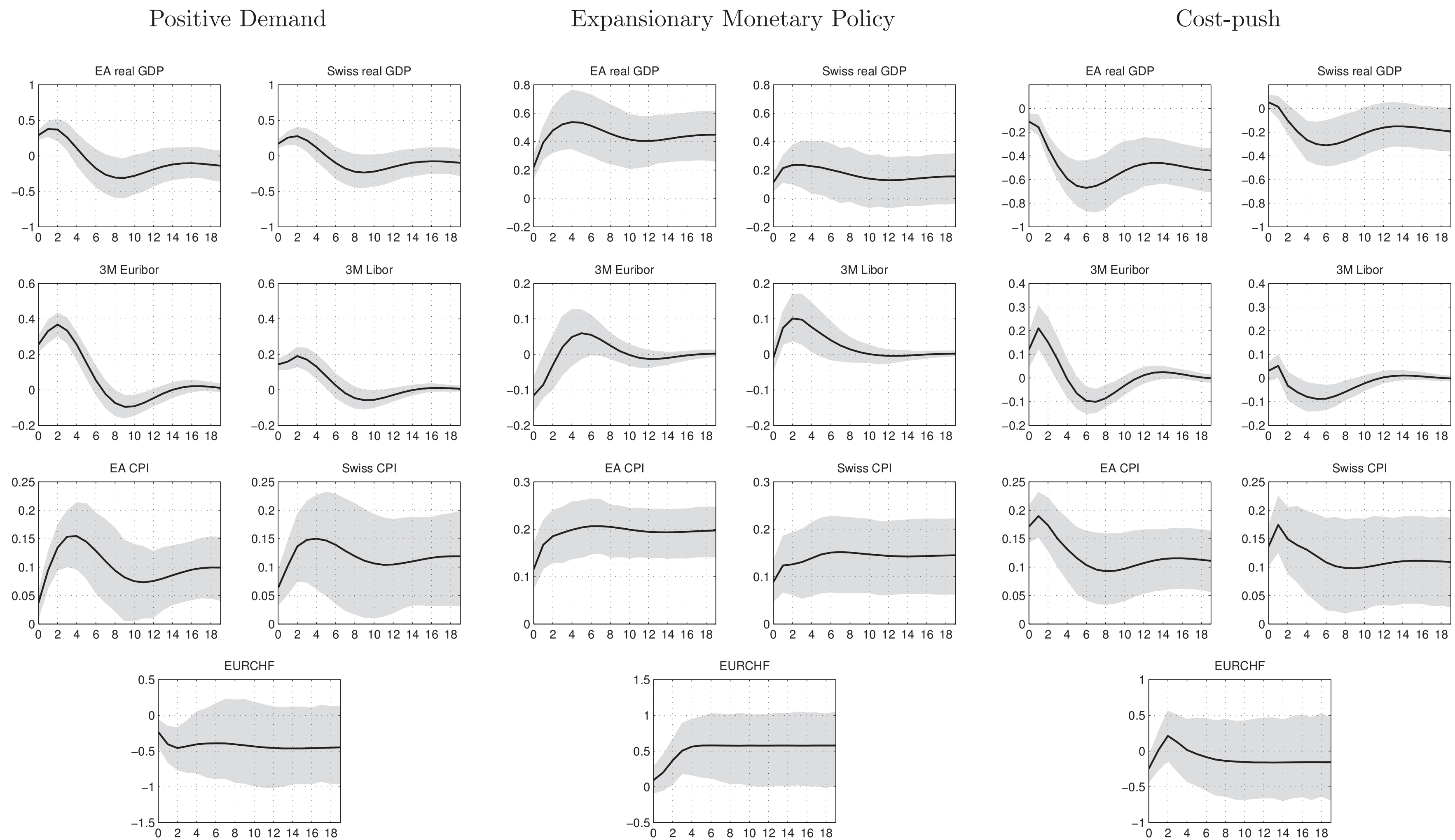
51

Figure 20 – Variance decomposition of Swiss variables and different price categories for the model with prior parameters $\pi_1 = 0.2, \pi_2 = 0.7, \pi_3 = 2$ and 4 lags in the state equation and 1 lag in the observation equation



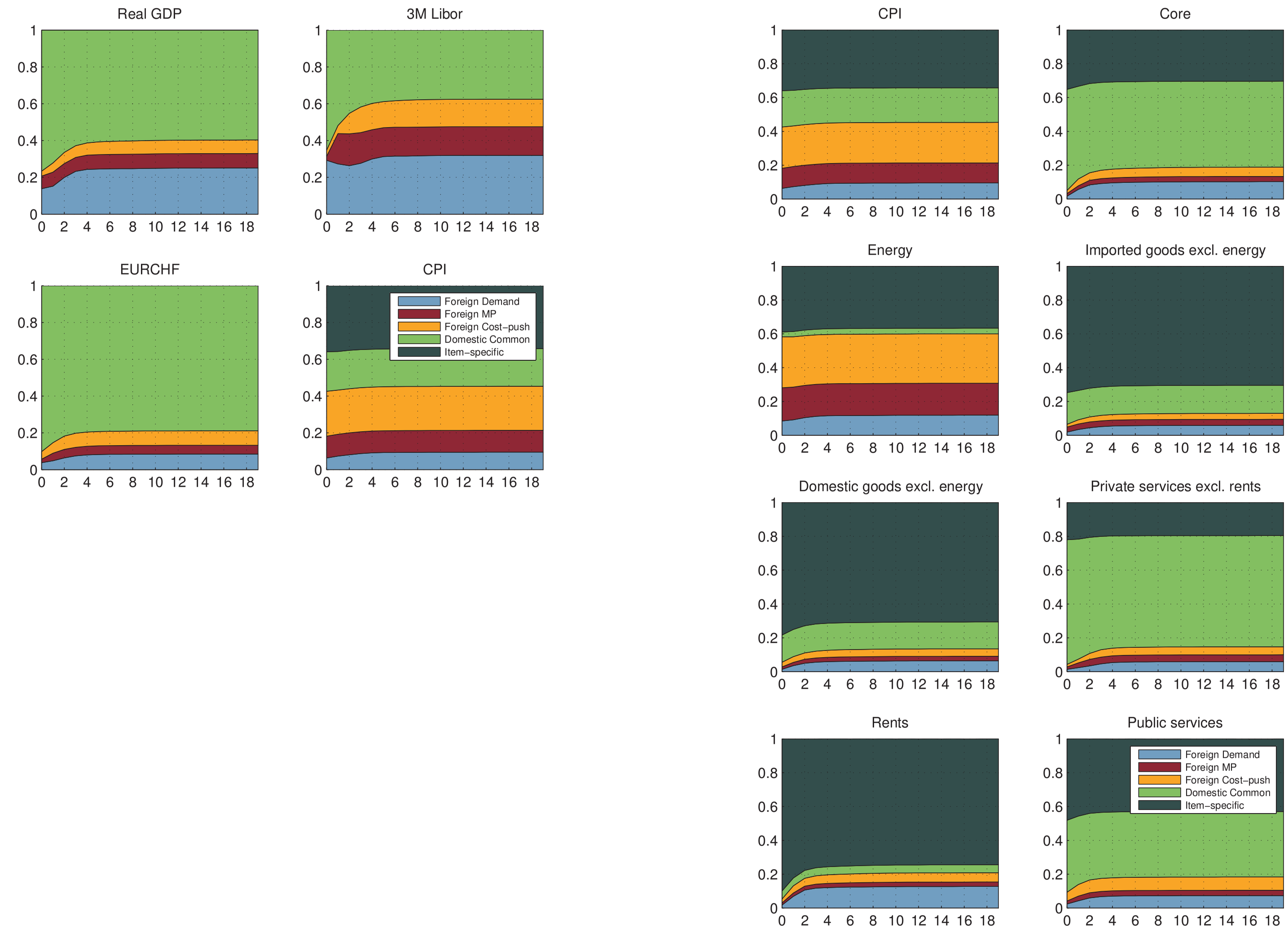
Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

Figure 21 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI for the model with HP de-trended variables



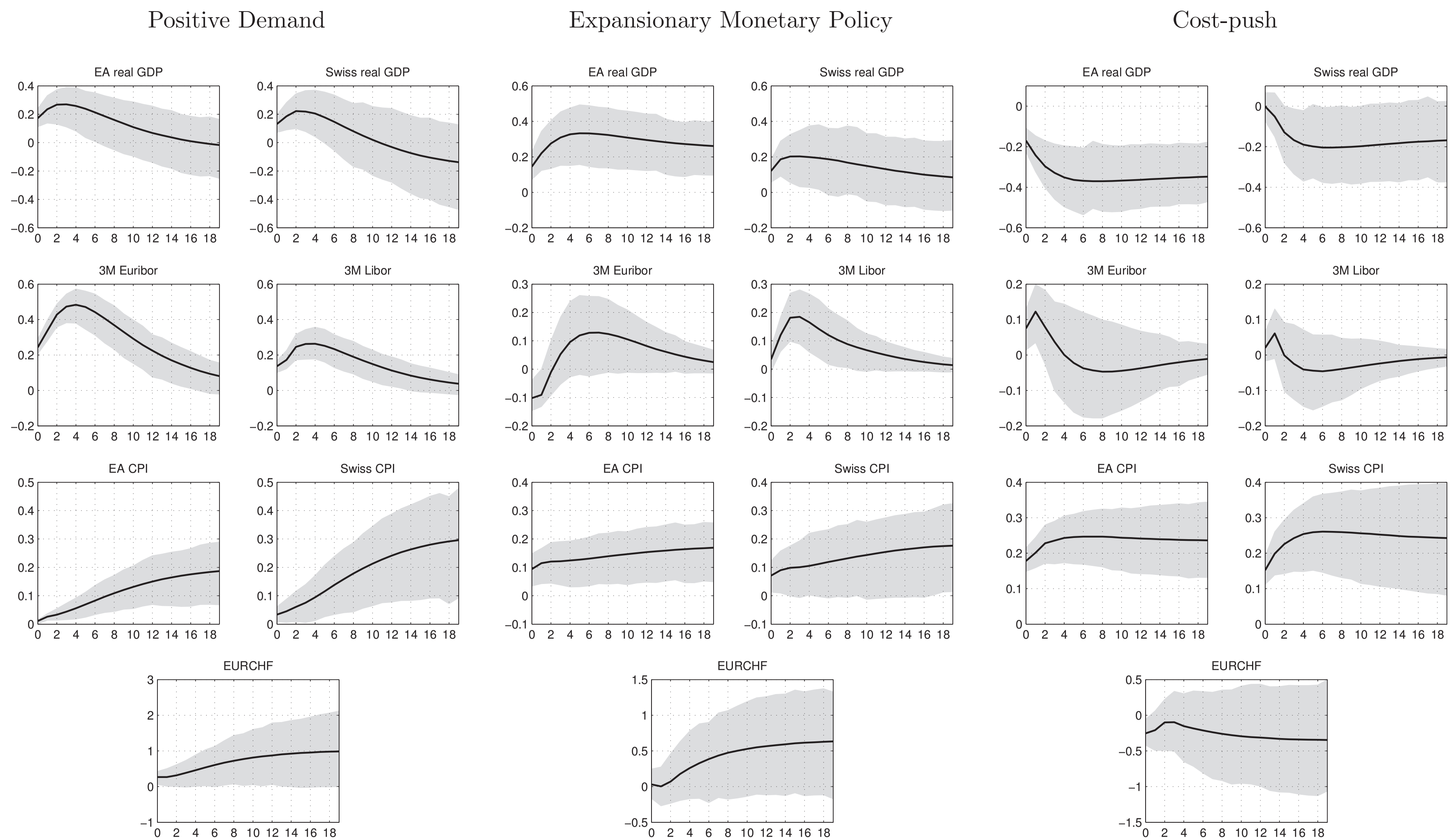
Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The response of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points of the HP filtered cyclical components. All other responses along the y-axis denote percentage changes of the HP filtered cyclical components.

Figure 22 – Variance decomposition of Swiss variables and different price categories for the model with HP de-trended variables



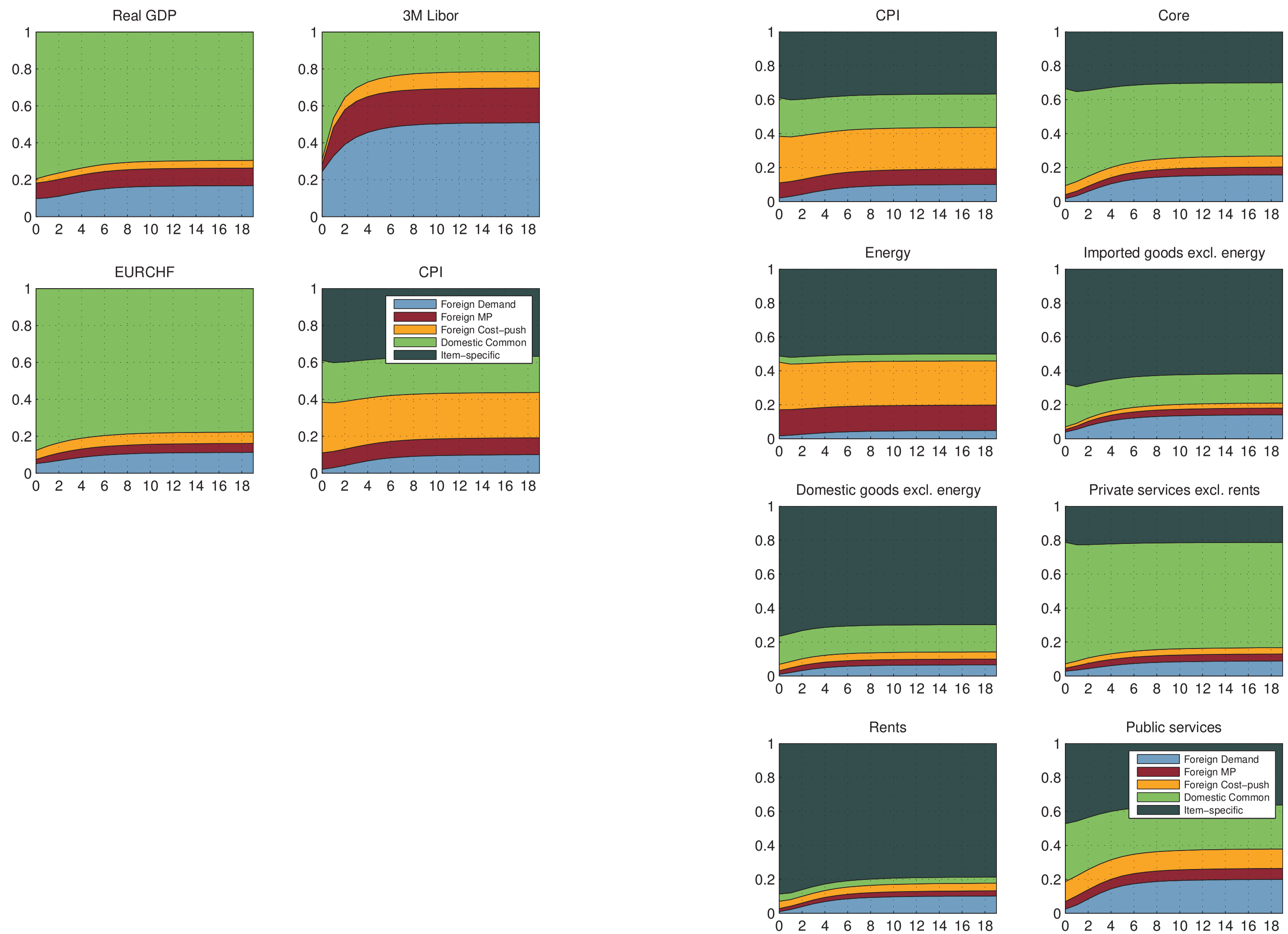
Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

Figure 23 – Impact of foreign inflationary shocks on common factors and aggregate Swiss CPI for the model estimated on data for 1992Q1 to 2007Q4



Note: The figure illustrates the impulse responses to one standard deviation structural shocks at horizons up to 20 quarters (along the x-axis). The median response is depicted by the bold black line. The light gray shaded area represents the 68% HPD interval. For all variables, the cumulative responses are shown except for the interest rates. The response of the interest rates along the y-axis can be interpreted as the annualized quarter-on-quarter change in percentage points. All other responses along the y-axis denote percentage changes.

Figure 24 – Variance decomposition of Swiss variables and different price categories for the model estimated on data for 1992Q1 to 2007Q4



Note: The figure illustrates the posterior mean of the forecast error variance decomposition of shocks (along the y-axis) at horizons up to 20 quarters (along the x-axis).

Recent SNB Working Papers

2017-7 Gregor Bäurle, Matthias Gubler and Diego R. Känzig: International inflation spillovers - the role of different shocks.

2017-6 Lucas Marc Fuhrer: Liquidity in the Repo Market.

2017-5 Christian Grisse, Signe Krogstrup and Silvio Schumacher: Lower bound beliefs and long-term interest rates.

2017-4 Toni Beutler, Robert Bichsel, Adrian Bruhin and Jayson Danton: The Impact of Interest Rate Risk on Bank Lending.

2017-3 Raphael A. Auer, Andrei A. Levchenko and Philip Sauré: International Inflation Spillovers Through Input Linkages.

2017-2 Alain Galli, Christian Hepenstrick and Rolf Scheufele: Mixed-frequency models for tracking short-term economic developments in Switzerland.

2017-1 Matthias Gubler and Christoph Sax: The Balassa-Samuelson Effect Reversed: New Evidence from OECD Countries.

2016-19 Jens H.E. Christensen and Signe Krogstrup: A Portfolio Model of Quantitative Easing.

2016-18 Jonas Meuli, Thomas Nellen and Thomas Nitschka: Securitisation, loan growth and bank funding: the Swiss experience since 1932.

2016-17 Rita Fleer, Barbara Rudolf and Mathias Zurlinden: Price change dispersion and time-varying pass-through to consumer prices.

2016-16 Gregor Bäurle, Daniel Kaufmann, Sylvia Kaufmann and Rodney W. Strachan: Changing dynamics at the zero lower bound.

2016-15 Adrian Jäggi, Martin Schlegel and Attilio Zanetti: Macroeconomic surprises, market environment and safe - haven currencies.

2016-14 Alain Galli: Sticky consumption and wealth effects in Switzerland.

2016-13 Gregor Bäurle and Rolf Scheufele: Credit cycles and real activity – the Swiss case.

2016-12 Silvio Schumacher: Networks and lending conditions: Empirical evidence from the Swiss franc money markets.

2016-11 Lucas Marc Fuhrer, Benjamin Müller and Luzian Steiner: The Liquidity Coverage Ratio and Security Prices.

2016-10 Nikola Mirkov, Igor Pozdeev and Paul Söderlind: Toward Removal of the Swiss Franc Cap: Market Expectations and Verbal Interventions.

2016-9 Severin Bernhard and Till Ebner: Cross-border Spill over Effects of Unconventional Monetary Policieson Swiss Asset Prices.

2016-8 Pinar Yeşin: Capital Flows and the Swiss Franc.

2016-7 Signe Krogstrup and Cédric Tille: On the roles of different foreign currencies in European bank lending.

SCHWEIZERISCHE NATIONALBANK
BANQUE NATIONALE SUISSE
BANCA NAZIONALE SVIZZERA
BANCA NAZIUNALA SVIZRA
SWISS NATIONAL BANK