How do individual sectors respond to macroeconomic shocks? A structural dynamic factor approach applied to Swiss data

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How do individual sectors respond to macroeconomic shocks? A structural dynamic factor approach applied to Swiss data*

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Abstract

Surprisingly little empirical work is available on how individual production sectors respond to macroeconomic shocks. The model developed in this paper quantifies the impact of monetary policy, exchange rates and external demand on the various production sectors of the Swiss economy. Our results show that such shocks are incompletely transmitted and that their effect is heterogeneous across sectors. The information gained through this work is new and a useful contribution for policy-makers as it enables them to assess the consequences of their decisions on the various sectors. The analysis is done in the framework of a structural dynamic factor model in order to cope with the large data dimensions. The model is estimated on Swiss data, but because it is carefully specified to capture the macroeconomic dynamics of a large set of variables in a small and open economy, its specification may also serve as a benchmark for other countries with this attribute.

JEL Classification: C1,C3,E33

Keywords: Sectoral value added, dynamic factor model, sign restrictions

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1 Introduction

Over the past decades, a large number of empirical models have been developed to understand better how the macroeconomy works and to quantify the likely effect of policy changes. These models are also widely used to produce forecasts and nowadays, play a crucial role in policy decision-taking. The models vary not only in terms of their type but also in terms of the variables they contain and what their prime focus is. Most models that focus on economic growth analyze aggregate GDP or GDP disaggregated into its main demand components such as consumption and investment.

We propose an alternative approach and put forward an empirical model that considers the economy from the production-side perspective, focusing on sector-specific value added. The production-side approach has two advantages. First, a production-side analysis makes it possible to quantify how aggregate shocks impact sector-specific value added and enables policy-makers to assess the consequences of their decisions on the various sectors. Indeed, a key finding of our work is that the economy reacts very heterogeneously across the production sectors. For example, output in the manufacturing sector is driven by different forces than output in the banking sector or in the construction sector. Second, when used for forecasting, the production-side approach makes it possible to align the model predictions with the day-to-day company news and survey results which almost always relate to the production side of the economy and only rarely to the demand side.[1] Against this background, surprisingly little work is available using an empirical model designed to analyze the effects of macroeconomic shocks on the various production sectors. This paper attempts to fill this gap. Specifically, we measure how growth in real value added in the thirteen main production sectors in Switzerland are influenced by a monetary policy shock, an exchange rate shock and a shock to foreign GDP. Through aggregation it is possible to estimate the impact of a given shock on aggregate GDP.

While the model has to be able to describe the large dimension of the data set, it should at the same time remain scarcely parameterized. This is a major challenge that we approach by conducting the analysis in the framework of a dynamic factor model. Essentially, such models describe the comovement between many time series by means of only a few common, dynamic factors. Each series is decomposed into a common

[1]A further advantage of the production-side perspective is that in the European system of national accounts, aggregate GDP is estimated from the production side, i.e. by aggregating up value added in the different sectors. A side-effect is that the inventories (which are calculated as a residual of consumption and investment to aggregate GDP) are sometimes strongly distorted as they also include quite large statistical errors. This makes the inventories neither explainable nor predictable, thus causing problems for demand-side models that ultimately aim to estimate aggregate GDP.

component and an idiosyncratic component. The latter takes up the variation that remains unexplained by the common component. This strategy reduces considerably the number of parameters that have to be estimated without heavily restricting the model's dynamic properties. Due to this very effective feature, dynamic factor models are becoming increasingly popular in empirical macroeconomics (for a survey, see Stock and Watson (2006)).

In contrast to most of the literature using the dynamic factor approach, we take a further step to achieve a representation that is as parsimonious as possible. Instead of estimating non-parametrically the unrestricted static factor space, we implement Bayesian estimation methods and take advantage of the possibility of imposing parametric constraints. Our model is similar to the factor augmented vector autregressive model (FAVAR) in Ahmadi and Uhlig (2012). However, as compared to their specification, we incorporate three important innovations. First, we allow observed variables to load not only contemporaneously on the common factors, but also on their lags. The increase in the number of estimated parameters is manageable and allows for asynchronous responses of observed variables to shocks. In principle, this property is not excluded in Ahmadi and Uhlig (2012) as their model can be interpreted as a static form of our dynamic specification. However, this would imply that the covariance matrix of the factors in their model is singular, as it is in the static form of our model. Second, following Kim and Nelson (1999), we allow the idiosyncratic component to be autocorrelated to allow for more realistic dynamic properties of the sector series. Third, we refine the scheme for the identification of the shocks by combining sign restrictions with zero restrictions. Following Ahmadi and Uhlig (2012), we use sign-restrictions to disentangle domestic monetary policy shocks from exchange rate shocks. However, we additionally implement zero restrictions to disentangle domestic shocks from foreign shocks. Specifically, we take advantage of the fact that Switzerland is a small open economy, allowing us to stipulate that foreign factors are exogenous.

Our empirical results show that the pass-through of shocks to the real economy is complex. Common shocks affect different sectors to a varying extent and with varying time lags. There are also important idiosyncratic elements. Our main findings are:

- In the short run, idiosyncratic factors dominate, accounting for more than 80% of the forecast error variance at one-quarter horizon. This explains why forecasting short-run dynamics with macroeconomic variables is so difficult. Over longer forecast horizons, however, over 50% of the forecast error variance in GDP can be explained by common shocks.

- A 1% rise in foreign GDP increases Swiss GDP by around 0.4%. Growth in manufacturing and restaurants & hotels sectors reacts especially strongly.
- A 1% rise in the exchange rate dampens GDP only slightly on impact, but leads to a cumulative negative change in GDP of 0.15% after three quarters. The financial sector (banking and insurance) in particular reacts sensitively to an appreciation.
- An increase in the CHF Libor by 1 percentage point leads to a cumulative decrease in GDP by around 0.8% after two years. Hence, there is a persistent real effect of monetary policy. The pass-through to the real economy proceeds sluggishly. The financial sector (banking and insurance) experiences the strongest impact.

To check whether these findings are realistic, we collect the estimated effects of the different shocks to aggregate GDP from previous studies with Swiss data and compare them to the response of aggregate GDP implied by our model. We conclude that our results are broadly in line with what other authors find, and take this as indication that our model is correctly specified. Nevertheless, as in all empirical analysis, the model type, the model specifications and the estimation sample have an impact on the results. Therefore, the findings shown in this paper are valid only within the specific framework of the model. In particular, we emphasize that the results may not be valid in periods with unusually large shocks such as the extreme appreciation of the Swiss franc in the third quarter of 2011.

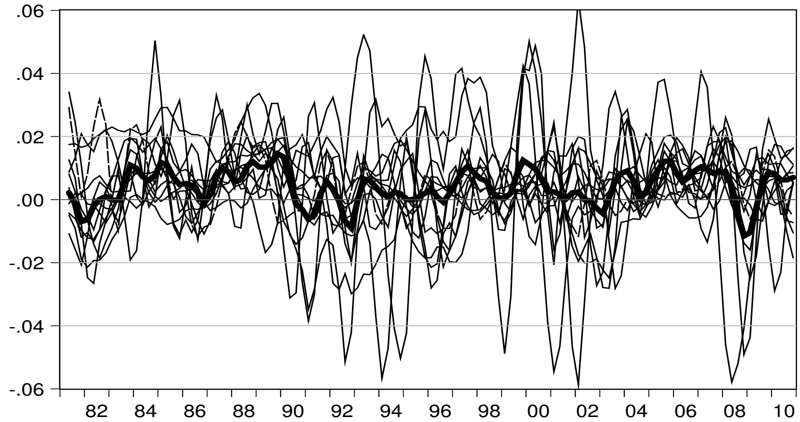
The remainder of the paper is organized as follows. In the next section, we present a number of sector-specific stylized facts. In section 3, we describe the specifications of our dynamic factor model and discuss the existing literature both on the production-side approach and dynamic factor models. In section 4, we present the main empirical results. Section 5 concludes the analysis. Details on data and methodology can be found in the appendix.

2 Comovement between sectors, stylized facts

In a first step we analyze the comovement of value added growth in the specific sectors in Switzerland. A high degree of inter-sectoral comovement suggests a relatively unmitigated pass-through of common shocks to all sectors, while low comovement indicates that shocks are heterogeneously transmitted to the various sectors and points to the existence of idiosyncratic elements.

The thirteen analyzed sectors[2] are depicted in Figure 1 together with aggregate Swiss GDP (thick line). This figure shows that there are many outliers and that the comovement between the production sectors in Switzerland is far from complete.

Figure 1: GDP (thick line) and value added of the 13 sectors analyzed, quarter-on-quarter growth rates, trend component



Note: For better visibility all series are smoothed with a Census X-12-ARIMA procedure.

In order to measure systematically the degree of comovement between sectors, one can look at the decomposition of the variance of aggregate GDP. The volatility of aggregate GDP depends on how strongly individual sectors fluctuate and how strong their comovement is. In technical terms, the variance of GDP is equal to the sum of all the variances of each sector plus twice the sum of all the pairwise covariances. The results shown in Table 1 indicate that the comovement term accounts for about half of the variance of aggregate GDP.

[2]The data employed in this paper are quarter-on-quarter growth rates of real value added in the thirteen main production sectors, adjusted for seasonal factors, between 1981-Q1 and 2010-Q4. The weighted sum of these sectoral value added growth series corresponds very closely to total GDP growth. More information on data sources in Appendix 6.1 and 6.2.

Table 1: Decomposition of the variance of aggregate GDP, 1981 Q2 - 2010 Q4

		contribution to aggregate variance, in %
Variance of total GDP	3.40	
Variance of the 13 analyzed sectors	3.31	
Sum of sector-specific variance	1.63	49.30
Comovement term	1.68	50.70

Note: Calculations done with year-on-year growth rates.

While two thirds of the concurrent pairwise correlations of sectoral value added are positive, the average pairwise correlation is low, amounting only to 0.1. The pairwise correlations show further that there is no particular group of sectors which concurrently commove especially strongly together. The concurrent correlations, however, only show part of the story. As shocks are not transmitted synchronically to the various parts of the economy, it is important to include leads and lags in the analysis. This is shown in Table 2, which depicts the correlation coefficients of each sector with the rest of the economy (i.e. total GDP excluding the observed sector), including various leads and lags. The sectors are ranked by their maximum positive correlation coefficient, highlighted in blue. The figures highlighted in gray are significant (the p-values of the coefficients in the corresponding bivariate regressions are under 0.10).[3]

The five sectors with the highest degree of comovement with the aggregate cycles are business services, restaurants & hotels, manufacturing, domestic trade (retail and wholesale), and banking. In recent years, these five sectors accounted for over 50% of GDP. Services to households, construction, health and public administration are somewhat less correlated. The insurance sector, private rental services and energy production show little comovement. On the other hand, there are also some counter-cyclical movements within the Swiss economy. Indeed, some of the correlation coefficients in Table 2 are significantly negative.

[3] The correlation coefficients are in some cases lower than the correlations commonly seen. This is mainly because we have excluded the observed sector from GDP. For example, the correlation of manufacturing and aggregate GDP amounts to 0.75. Furthermore, as the seasonally adjusted data is quite erratic it is normal that the correlations are relatively low. Using smoother series, such as the trend component calculated with a Census X-12-ARIMA procedure, the correlations increase by 20 to 30%.

Table 2: Correlation of specific sectors with rest of the economy, 1981 Q2 - 2010 Q4

	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4
BusServ	-0.01	-0.05	-0.03	0.08	0.20	0.40	0.28	0.33	0.16
RstrHlt	-0.05	0.16	0.15	0.28	0.34	0.28	0.39	0.27	0.26
Manuf	-0.14	0.06	0.03	0.14	0.36	0.10	0.25	0.04	0.03
DomTrade	-0.10	0.02	-0.06	0.22	0.36	0.19	0.24	0.14	-0.05
Bnk	0.26	0.33	0.35	0.14	-0.06	-0.37	-0.21	-0.26	-0.26
Const	0.14	0.08	0.24	0.27	0.17	0.05	0.14	-0.11	-0.04
HhServ	0.09	-0.04	0.06	0.26	0.17	0.17	0.15	0.03	0.09
Hlth	-0.16	-0.19	-0.07	0.10	0.21	0.23	0.21	0.20	0.12
Admin	0.03	-0.05	0.04	0.11	0.13	0.06	0.15	0.17	0.19
TransCom	-0.13	-0.20	0.05	0.04	0.17	0.07	0.15	0.13	0.02
Energ	0.17	0.02	-0.03	0.04	-0.05	0.14	-0.02	0.08	0.15
Rent	0.08	-0.01	-0.05	0.08	0.10	-0.05	-0.03	-0.17	-0.24
Insur	-0.06	-0.10	-0.01	0.05	0.09	0.03	0.10	-0.05	0.03

Note: The rest of the economy is defined as GDP minus the specific sector. For all highlighted correlations, the p-values of the coefficients in the corresponding bivariate regressions are below 0.10.

Sectors showing a lead on the rest of the economy, such as banking, probably react quicker to macroeconomic shocks than other sectors. On the other hand, sectors which comove with a lag on the rest of the economy, such as business services, are possibly not influenced directly by common factors but through the propagation of shocks due to sectoral linkages. The fact that sectors do not commove synchronically indicates that it is important to model sectors in a dynamic way.

In the next section, we present a specific version of a structural dynamic factor which is suitable for a comprehensive analysis of sectoral series in relation to aggregated shocks.

3 A structural dynamic factor model

To isolate and quantify the impact of economic shocks on sector-specific value added at different horizons, we need to specify an empirical model which is able to describe the dynamic interaction between the main macroeconomic drivers of the Swiss economy and the thirteen sectors. This presents a challenge for the empirical modeling strategy. On the one hand, the model has to be general enough to be a realistic representation of the data. The statistics in the previous section suggest that shocks influence the sectors unevenly, to varying degrees of magnitude and at different lags. Our model has to be able to replicate such dynamics. On the other hand, it should be as parsimonious as possible. A standard vector autoregression (VAR) in all observed variables definitely entails too many free parameters. Another possibility is to estimate a separate model for each sector, including value added in this sector, aggregate output and other macroeconomic variables (see e.g. Fars and Srour (2001) and Ganley and Salmon (1997)). A major drawback of a non-simultaneous estimation is, however, that the estimated aggregate dynamics may differ within the set of sectoral models; and no matter what identification scheme is applied, the estimated shocks in one model are possibly inconsistent with the shocks in other models.

We propose a dynamic factor structure instead. Such models have successfully been applied for forecasting economic time series (see e.g. Stock and Watson (2002)) and also to analyze the effect of monetary policy (see e.g. Bernanke and Boivin (2003), Bernanke, Boivin, and Eliasz (2005), Boivin and Giannoni (2006) and Ahmadi and Uhlig (2012)). In factor analysis, a large set of observed variables respond to a few common factors. The factors themselves follow a dynamic process, usually approximated by a vector autoregressive model. By allowing the observed variables to be related to potentially unobserved factors and their lags, the model can reproduce diverse joint dynamics of a large number of series, such as asynchronous responses to shocks. At the same time, the number of estimated parameters remains reasonably low.

3.1 Model specification

We assume that the following specification of a dynamic factor model is suitable. The observation equation relates the observed variables to observed and unobserved common factors:

$$X_t^S = \lambda(L) \begin{pmatrix} f_t^S \\ X_t^M \end{pmatrix} + v_t \tag{1}$$

X_t^S is the vector of sectoral value added with dimension N_S. X_t^M are measures of the q^M observed common factors such as interest rates or exchange rates and f_t^S is the q^S-dimensional vector of unobserved factors. The sectoral variables X_t^S load on both unobserved and observed common factors and their lags with $\lambda(L) = \lambda_1 + \lambda_2 L + \lambda_3 L^2 + \ldots + \lambda_p L^{p-1}$. v_t is an N_S-dimensional vector of idiosyncratic components. Following Stock and Watson (2005) and Boivin and Giannoni (2006), we allow v_t to be autocorrelated of order one by specifying $v_t = \Psi v_{t-1} + \xi_t$. The state equation describes the joint dynamics of the common factors:

$$\phi(L) \begin{pmatrix} f_t^S \\ X_t^M \end{pmatrix} = Q\varepsilon_t \tag{2}$$

ε_t contains the common shocks. In our empirical analysis, we will focus on monetary policy shocks, exchange rate shocks and shocks to foreign demand. The factors follow a vector-autoregressive process with $\phi(L) = I_q - \phi_1 L - \phi_2 L^2 - \ldots - \phi_p L^p$, where $q = q^S + q^M$. The shocks ξ_t and ε_t are assumed to be Gaussian white noise:

$$\begin{pmatrix} \xi_t \\ \varepsilon_t \end{pmatrix} \sim iN\left(\begin{bmatrix} 0_{N^S \times 1} \\ 0_{q \times 1} \end{bmatrix}, \begin{bmatrix} R & 0_{N^S \times q} \\ 0_{q \times N^S} & I_q \end{bmatrix} \right)$$

The factors are related to the q common shocks in ε_t with the $q \times q$-matrix Q. The common shocks ε_t and the idiosyncratic shocks ξ_t are mutually uncorrelated, such that R is a diagonal matrix of dimension $N_S \times N_S$. Thus, the idiosyncratic shocks ξ_t are orthogonal to the rest of the economy at all leads and lags. This does not mean, however, that we exclude shocks originating in a specific sector spilling over to other parts of the economy. If they are empirically relevant, these shocks are interpreted as common shocks.

Our model is similar to Ahmadi and Uhlig (2012). However, as compared to their specification, we incorporate three important innovations. First, we allow observed variables to load not only contemporaneously on the common factors, but also on their lags. The increase in the number of estimated parameters is manageable and allows for asynchronous responses of observed variables to shocks. In principle, this property is not excluded in Ahmadi and Uhlig (2012) as their model can be interpreted as the static form of our specification. However, this would imply that the covariance matrix of the factors in their model is singular, as it is in the static form of our model (see Appendix (6.3)). We explicitly take these restrictions on the stochastic rank of the factors into account, allowing us to expand the dimension of the state vector without having to deal with an excessive increase in the number of free parameters. Second, we allow the idiosyncratic component to be autocorrelated to allow for more realistic dynamic properties of the sector series. Third, besides sign restrictions as implemented in Ahmadi and Uhlig (2012), we also make use of zero restrictions. In particular, we take advantage of the fact that Switzerland is a small open economy, allowing us to stipulate that foreign factors are exogenous. Specifically, we assume that foreign variables such as foreign GDP, foreign interest rates, oil prices or foreign stock prices do not react to domestic shocks at all lags by restricting $\phi(L)$ and the covariance matrix $Var(Q\varepsilon_t) = QQ'$ appropriately. Note that this requires a refinement of the procedure to identify the shocks based on sign restrictions (see section 3.2.2).

The model is estimated using Bayesian methods. It has become standard to use a Gibbs Sampler, iterating over the following two steps (see 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 such that we obtain this number of draws from the posterior distribution of parameter. Furthermore, we experiment with different values for the initial draw Θ_0 and ensure that this does not influence the results.

The two steps in the Gibbs-Sampler are implemented as follows. We use the algorithm of Carter and Kohn (1994) and Frühwirth-Schnatter (1994) to sample from the distribution of the factors. Given the factors, the coefficients in (1) can be determined using standard methods for a linear regression with autoregressive errors. 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 (see e.g. discussion in Bäurle (2013)). The determination of the coefficients describing the factor dynamics reduces to the estimation of a standard VAR. We use an improper prior for these coefficients and implement the restrictions reflecting the exogeneity assumption on foreign factors following Bauwens, Lubrano, and Richard (1999). Note that the likelihood is only informative about $\Sigma = QQ'$, but not 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 section 3.2.2. Further details on the estimation method and the exact specification of the prior are given in Appendix 6.4.

3.2 Model implementation

We now describe the implementation of our empirical model. When implementing the estimation strategy, a number of decisions regarding data selection and model dimension have to be made. Most importantly, a strategy for identifying the primitive shocks has to be chosen. As it is hardly possible to select a specific implementation based on objective criteria, we attempt to only narrow the range of reasonable choices based on preliminary data analysis. We then derive the results based on different plausible implementations and report the robustness of the results.

3.2.1 Data selection and transformation

The aim of our model is to measure the impact of common shocks on the various production sectors. The sectors enter the model as quarter-on-quarter growth rates of the sector-specific, seasonally adjusted, real value added from the second quarter of 1981 to the last quarter of 2010. Aggregated, these series correspond very closely to total GDP (see Figure 13 in Appendix 6.2).

The common shocks cause changes in nominal exchange rates, nominal short-term interest rates and foreign output. Proxies for these variables are an export-weighted nominal exchange rate index, the 3-Month Libor for the short-term interest rate and, as measure of foreign output, the export-weighted GDP of Switzerland's main export partners. We additionally include a price measure, as our strategy for identifying monetary policy shocks hinges on assumptions about the reaction of prices to these shocks. Specifically, we use the Swiss Consumer Price Index (CPI) excluding rents as price measure. We exclude rents from the CPI as they are tied to mortgage rates by law and therefore react in a different way to monetary policy changes than would be implied by standard theory.[4]

As Sims (1992) argues, it is essential not to omit information which has been used by the authorities for their monetary policy decisions. We have therefore analyzed a set of further variables that are tightly related to monetary policy.[5] It turns out that, among these variables, euro short-term interest rates and total credit volume show an empirical relevance. The omission of these two variables leads to a bias in the estimated reaction of sectoral value added series to monetary policy shocks.

[4] Rents are tied to a so-called 'reference rate' which is determined based on the average mortgage rate and therefore positively linked to market interest rates. Thus, rents mechanically increase on rising interest rates.

[5] Swiss M2, total credit volume, euro short-term interest rates, oil prices, MSCI as a measure of stock prices, and population.

For all other variables, the estimated results proved to be robust to their omission.[6] Hence, this 'baseline' specification includes six factors: the CPI excluding rents, the export-weighted nominal exchange rate, domestic and foreign short-term interest rates, and credit volume. These factors enter the model as quarter-on-quarter growth rates except for the interest rates, which are left as levels. Following the literature, the series are standardized such that they have variance equal to one. After the estimation, the quantitative results are transformed back into the original scale.

3.2.2 Identification of primitive shocks

As described in section 3.1, we first derive the posterior distribution of Σ and then, in a second step, impose certain restrictions based on economic considerations to pin down the distribution of Q. The choice of restrictions on Q is important, as the structural interpretation hinges on the relation between factors and ε_t. We use different methods to identify this relationship.

Zero restrictions to identify foreign shocks: We implement the standard 'small open economy' assumption that domestic shocks do not impact foreign variables by imposing suitable zero restrictions on the Q. Furthermore, we rely on a standard Cholesky to determine shocks to foreign GDP. The ordering is such that shocks to foreign GDP are first. That is, surprise changes in foreign GDP are exclusively attributed to this shock. In other words, we measure the effect of a change in foreign GDP without explicitly pinning down the fundamental source of this change. The implicit assumption that the effect of foreign GDP on domestic real activity does not depend on the source of the shock may seem quite strong. It turns out, however, that our findings are rather robust to the ordering, also in relation to the inclusion of other variables such as oil prices or stock prices. This suggests that the main impact of foreign shocks is through shifts in foreign GDP, such that the exact source of the shock is not decisive for a reaction of the domestic economy.

Sign restriction approach for shocks to the exchange rate and monetary policy shocks: For exchange rate shocks and, in particular, for monetary policy shocks, zero restrictions on Q are not easily justified. On the one hand, an immediate reaction of exchange rates to interest rates cannot be excluded. Following Uhlig (2005), we use restrictions on the sign of the response of selected elements

[6] Section 4.4 discusses our robustness analysis in more detail.

of X^M_{t+h} to shocks at time t to identify these shocks, but do not directly impose restrictions on the reaction of X^S_{t+h}.

Specifically, we assume that an interest rate shock which pushes up interest rates has a negative impact on prices and leads to an appreciation of the Swiss franc. Exchange rate shocks, on the other hand, push up the exchange rate (corresponding to an appreciation) decrease prices, and lead to cuts in the interest rate. This identification is in line with economic theory as it reconciles monetary policy and exchange rate shocks - the latter are usually labeled 'risk premium' shocks - in a dynamic stochastic general equilibrium model along the lines of Monacelli (2005) and estimated with Swiss data by Leist (2011).

In our baseline specification, we impose the restrictions for $h \leq 1$, approximating the number chosen by Uhlig (2005), who uses 5 periods in his analysis based on monthly data. To implement these restrictions, but keeping the zero restrictions described above, we refine the method proposed by Uhlig (2005) by only rotating the 'domestic part' of the Q matrix. By drawing 20 impulse-response function per draw, we get around 8000 accepted draws to calculate our impulse-response function. Based on these draws, we calculate highest probability density (HPD) intervals 'pointwise', that is for each horizon separately.

3.2.3 Selecting the model dimensions

In classical factor analysis, it is standard practice to use information criteria to determine the model dimensions. While in our Bayesian setting, a formal model comparison based on posterior data densities would be preferred, this is inherently difficult because the large dimension of our model and the dependence on prior distributions. Therefore, we use information criteria-based evidence to narrow the range of reasonable numbers for the number of factors.

To our knowledge, there is no criterion that is explicitly designed for our restricted version of a general factor model. However, the criterion by Bai and Ng (2007) makes it possible to determine not only the number of static factors ($r = pq$ in our model), but also the dimension of the primitive shocks driving the economy (q in our model) for a factor model which nests our specification. With our sectoral data, their criteria point to a large number of static factors ($r = 13$ in the standard specification of the test), but only a small number of primitive shocks. The criterion denoted by q_3 in their paper based on the correlation matrix points to $r = 1$. This criterion is most suitable for $N = 20$ and $T = 100$ according to their simulations, which is very close to the dimension of our data set. Our findings are robust to the lag length in the auxiliary VAR. That is, from the point of view of this criterion, our dynamic factor structure with a potentially large number of static factors but only a few dynamic factors seems to be suitable. We also carried out the test by first conditioning on our observed factors and their lags. Additionally, we calculated the results for the filtered sectoral series using an univariate AR(1) process estimated by OLS for each sectoral series. The rationale behind this is that in our factor model, we allow the idiosyncratic component to be autocorrelated of order one. In most of the cases, the criterion confirms that the number of dynamic factors is one. Only in a few cases, does the criterion point to two factors. Therefore, in our 'baseline' specification, we include one unobserved factor, but check the robustness of our results by adding more unobserved factors (see section 4.4).

The lag-length p remains to be specified. In principle, in our specification, this number is implicitly defined through the number of static and dynamic factors as $pq = r$. Given a high number of static factors and $q = 1$, we would therefore end up with a high number for p. However, selecting p based on this relationship is very sensitive to the choice of q. Furthermore, the procedure proposed by Bai and Ng (2007) does not take into account such a restriction. For these reasons, it does not seem appropriate to exploit this relationship. Therefore, we set $p = 4$ initially, but incorporate uncertainty in this regard by testing the robustness of our results with respect to p in section 4.4.

4 Empirical results

Having estimated the model, we are in a position to study a number of different aspects. First, we analyze the unobserved factor. It turns out that this factor is quite closely related to GDP growth, picking up aggregate fluctuations which are not directly explainable by observed common factors. Second, we decompose the variance of the sectoral and aggregate series into contributions from different sources. This allows us to assess the importance of the idiosyncratic shocks on the one hand and the different macroeconomic shocks on the other. Third, we describe how the shocks impact sectoral and aggregate value added. We show that sectors respond quite heterogeneously to the common shocks.

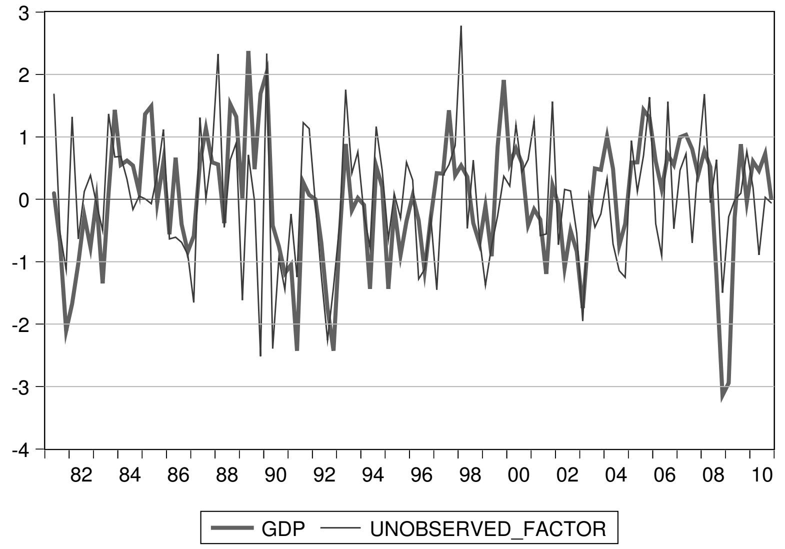
4.1 The unobserved common factor

Sector-specific growth is influenced by an unobserved factor which captures common dynamics left unexplained by the observed factors.[7] As shown in Figure 2 the unobserved factor is quite closely related to the quarter-on-quarter growth of GDP, a finding which is confirmed by a correlation coefficient of 0.47. This indicates that the unobserved factor captures the effects of common shocks, such as aggregate technology shocks or changes in overall business and consumer confidence, which have an impact on many parts of the economy but are not always caused by observed macroeconomic variables. A further source of fluctuations in the unobserved common factor could be sector-specific technology shocks spilling over to the rest of the economy.[8]

[7] We have conducted extensive robustness checks for omitted factors (see section 4.4) but have not found any further variables with a relevant impact on the empirical results.

[8] Disentangling these shocks from 'true' common shocks would be possible using information about the input-output structure of the sectors under a set of assumptions on the production technology, as shown in Foerster, Sarte, and Watson (2008). Unfortunately, information on the input-output structure is incomplete for Switzerland, hindering the implementation of this approach.

Figure 2: Estimate of unobserved factor (median) together with quarter-on-quarter GDP growth, normalized



4.2 Forecast error variance decomposition

Our model allows us to assess the sources of variation in each series. The results show that a major part of the short-term variation is due to idiosyncratic shocks, while in the long run the different common components gain relevance. This conclusion is based on forecast error variance decomposition, which measures the fraction of the variance of the forecast error attributable to a particular shock at different horizons.

We first decompose the forecast error variance into an idiosyncratic component and a common component. Table 3 shows the median contribution of common shocks relative to the total variance for each sector n for horizons up to three years. In the short run, the impact of idiosyncratic factors is decisive and accounts for more than 80% of the forecast error variance in the specific sectors. In other words, common shocks are not important for short-term forecasting. Almost all of the forecast error comes from idiosyncratic shocks, which may be interpreted as measurement error or as some fundamental source of variation which is orthogonal to influences common to other series. However, the fraction of the idiosyncratic shocks declines with increasing forecast horizons. This is because idiosyncratic shocks are not persistent and tend to cancel each other out over time. In contrast, common shocks have a persistent impact and therefore drive the results in the long term.

An interesting feature is that the importance of the idiosyncratic shocks is lower for aggregate GDP than for most individual sectors.[9] While the contributions of common shocks in the sectoral series are mutually correlated, the idiosyncratic shocks are independent on one another. In aggregate, they therefore counterbalance each other. We find that for aggregate GDP the contribution of common shocks in the one-step prediction error variance is 12%, increasing rapidly rapidly to more than 40% after one year. At a 16-quarter horizon, over 50% of variation in aggregate GDP can be explained by common shocks. This is shown in the last line of Table 3.

Table 3: Percentage of forecast error variance caused by common shocks (median of decomposition calculated for each draw), in %

Horizon (in quarters)	1	2	3	4	8	12	16
Manufacturing	15	25	30	33	38	40	41
Banking	12	15	21	25	31	34	36
Insurances	8	13	17	22	29	32	34
Restaurants & hotels	6	16	24	28	39	45	48
Business services	6	9	17	22	30	34	36
Domestic trade	6	13	19	24	31	34	35
Transport & comm.	7	12	17	22	28	30	31
Rental income	20	35	42	46	54	57	58
Construction	7	10	16	22	32	38	41
Energy	7	14	19	24	31	33	34
Health	8	11	17	22	30	33	35
Public administration	8	13	16	21	30	36	40
Services to households	7	13	23	28	36	41	44
GDP	12	24	32	38	47	51	53

Further, the contribution of the different shocks varies quite strongly across sectors. In Figure 3, the contribution of shocks to foreign GDP, exchange rate shocks, monetary policy shocks and the non-identified common domestic shocks to the forecast error variance of the sectors are shown. For manufacturing, shocks to foreign

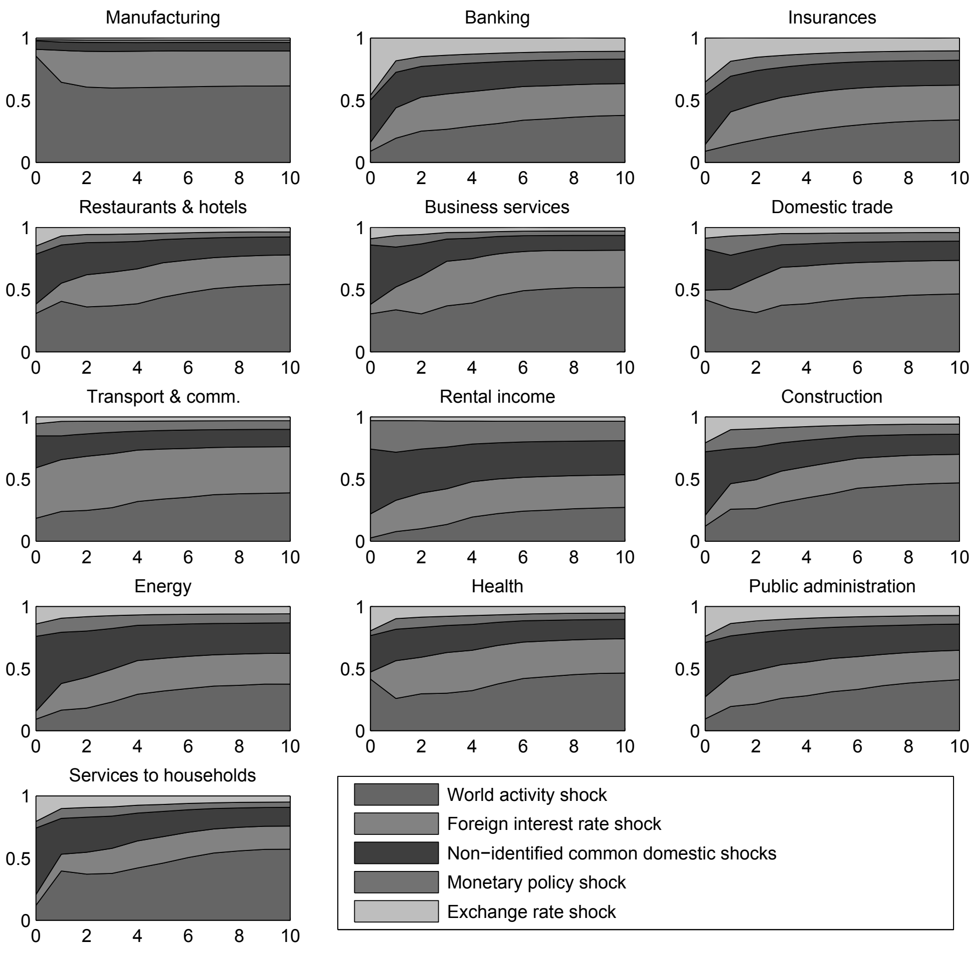
[9] The fraction of the forecast error variance due to common shocks for aggregate GDP is calculated as

$$\frac{Var(\omega X_{t+H}|F_t, v_{t+h} = 0, \forall h > 0)}{Var(\omega X_{t+H} \mid F_t)} \tag{3}$$

with ω representing the sectoral shares. It becomes apparent that for aggregate value added, common shocks are clearly more important than for single sectorial series.

GDP are by far the most important component. Monetary policy shocks and the other, non-identified common domestic shocks also have a relevant impact. The impact of the exchange rate is rather small. For the financial sector (banking and insurances) the impact of the exchange rate is more relevant. For tourism, the exchange rate also plays a certain role. However, foreign GDP and domestic factors remain the most important contributors. Clearly, for domestically oriented sectors, such as construction, rental services and domestic trade, the domestic factors play an important role.

Figure 3: Forecast error variance decomposition (median of decomposition calculated for each draw)



4.3 Impact of common shocks

Not all sectors are influenced in the same way by a particular shock. In fact, the pass-through of shocks to the real economy follows a complex pattern. This is because, beside the direct impact, sectors also react indirectly to a shock through inter-sectoral dependencies. Furthermore, a shock to one common factor has repercussions on the other common factors which in turn also influence sectoral growth. Depending on the sectors, these second-round effects may either accentuate or counterbalance the direct impact of a shock. The model cannot differentiate whether a sector is directly influenced by a shock or if it reacts to second-round effects. However, a delayed response of a sector to a shock may be an indication that the indirect channels are predominant.

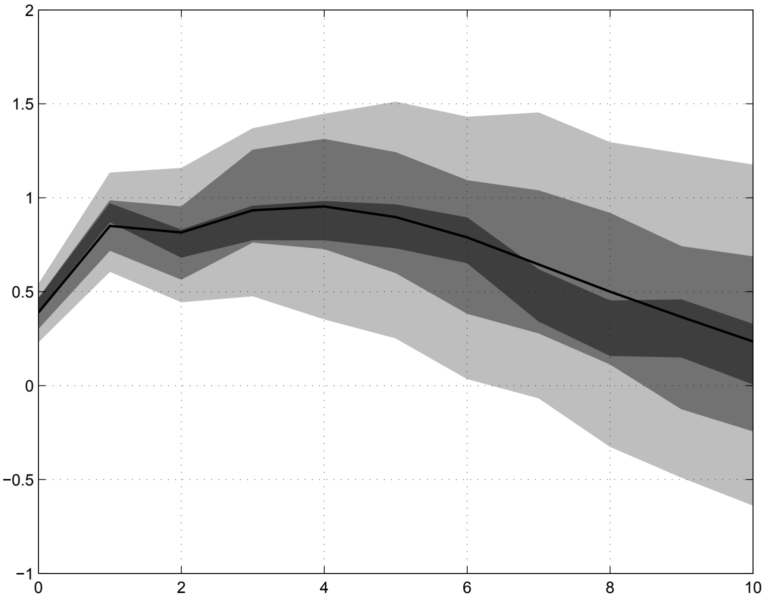
To understand the pass-through of common shocks in greater detail, we use impulse response functions (IRF) as a suitable way to measure how the variables react to shocks at different horizons. The responses are shown in cumulative log differences. First we show the impulse response functions of shocks to foreign GDP, then to the exchange rate and finish by showing the impact of a monetary policy shock. For each shock, we compare the responses of common shocks on aggregate GDP implied by our model with those published in previous studies and find that they are broadly in line with each other (see Appendix 6.5 for an overview of empirical results in previous studies applied to Swiss data). We take this as evidence that our model is correctly specified and that the sectoral results are realistic.

4.3.1 Impact of a shock to foreign GDP

Switzerland is closely linked with the international economy through large inflows and outflows of goods and services. Therefore, one would expect the Swiss economy to react quite distinctly to a shock to foreign GDP. Our results confirm that this is the case.

Figure 4 depicts the median and the highest posterior density (HPD) intervals of the response of Swiss GDP to a shock to foreign GDP. Here, Swiss GDP is defined as the weighted average of the 13 sectors analyzed. A 1% shock to foreign GDP leads to a cumulative rise in foreign GDP of slightly more than 2% after three quarters (see Figure 5) which translates to a cumulative increase in aggregate GDP of 0.9% after three quarters. In other words, the elasticity of Swiss GDP to foreign GDP is around 0.4. This result is in line with the elasticity of 0.4 in Cuche-Curti and Natal (2010) and 0.25-1 in Assenmacher-Wesche and Pesaran (2009).

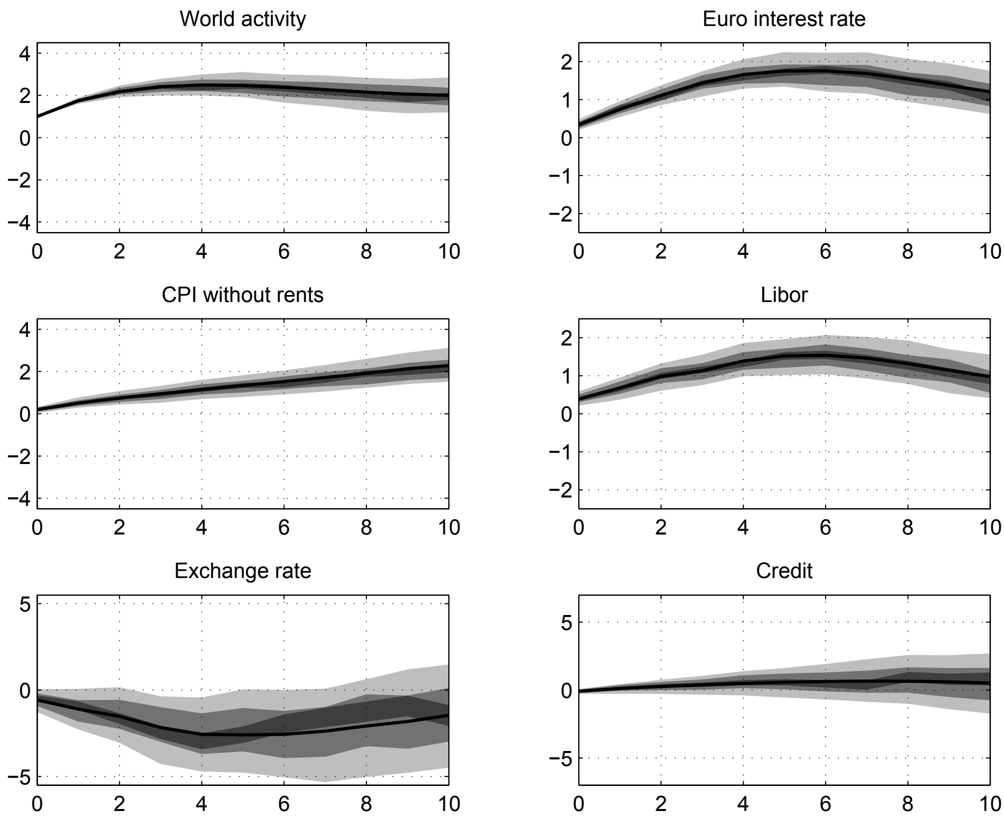
Figure 4: Cumulative impact of a shock to foreign GDP on Swiss GDP



Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to a shock increasing foreign GDP by 1%

According to our model, however, this growth effect is not permanent. A plausible explanation is that a shock to foreign GDP has repercussions on the other common factors. Indeed, as shown in Figure 5, a positive shock to foreign GDP leads to quite a pronounced rise in domestic interest rates as a reaction to the increase in the CPI. This strong increase in the interest rate subsequently dampens GDP growth.

Figure 5: Cumulative impact of a shock to foreign GDP on common factors



Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to a shock increasing foreign GDP by 1%

The sectoral impulse response functions confirm that, in most cases, the sectors which are the most exposed to the international economy react more quickly and more strongly than the domestic oriented ones. A measure of international exposure could be the share of production which flows into exports. Unfortunately, there exists no reliable statistics which reveals the share of exported production at the sectoral level for Switzerland. An approximation with current account data indicates that in 2008, manufacturing exported nearly 70% of its production, banking around 30%, restaurants & hotels 25%, the energy sector 21%, and domestic trade 18%.[10] This information gives us a broad idea of the sensitivity of the various sectors to a shock to foreign GDP. The IRFs are shown in Figure 6.

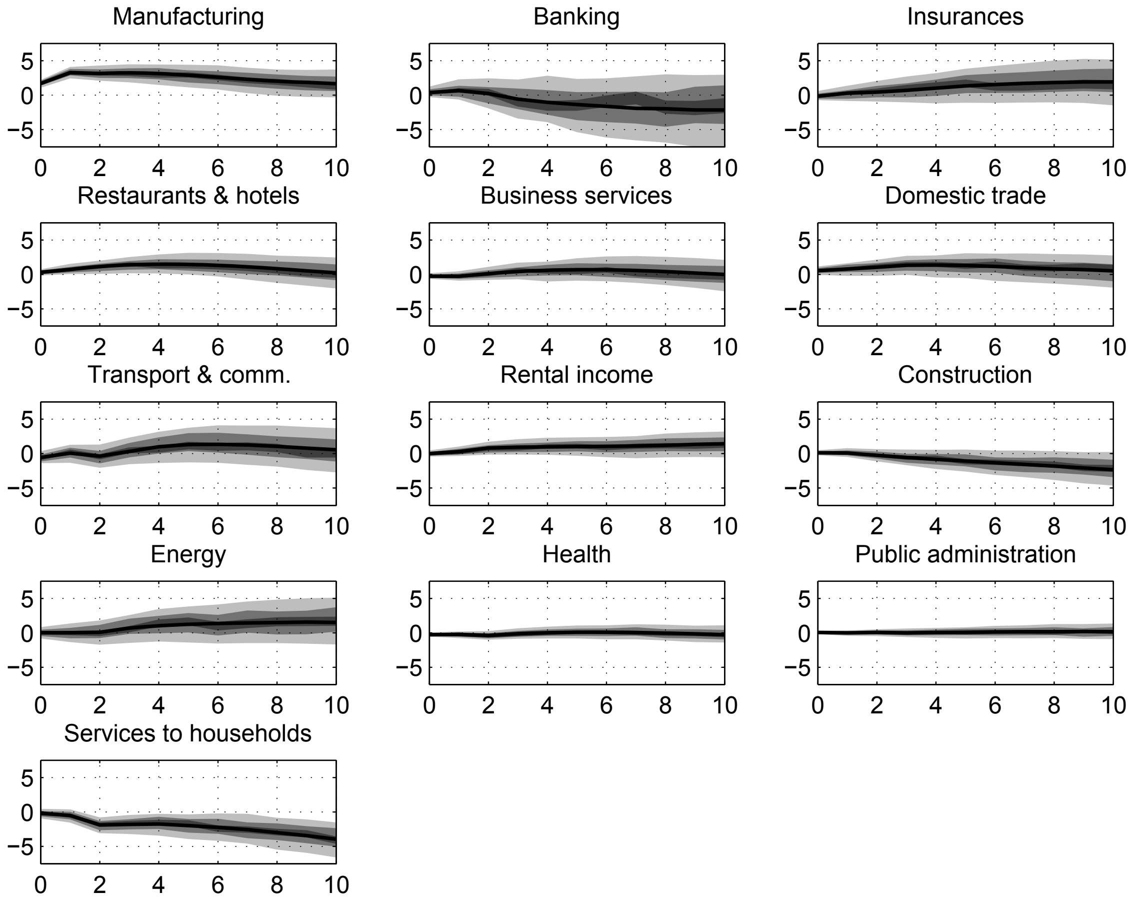
As expected, manufacturing responds strongly and rapidly. A rise in foreign GDP of 1% implies a rise in manufacturing value added of 1% on impact. The effect

[10] Only an approximate estimation is feasible as it is not possible to distribute all the different categories of exports from the current account exactly to the production sectors.

increases to 1.4% in the first quarter. This strong reaction may be attributed to the fact that the Swiss manufacturing sector exports a large share of pro-cyclical goods, such as equipment goods which typically rise (decline) stronger than overall growth. The repercussion of a shock to foreign GDP on the exchange rate provides an additional positive impact. Restaurants & hotels, the energy sector and domestic trade also show a quick and positive reaction to a rise in foreign GDP with cumulative responses of approximately 1.5%, 1% and 1.3% after four quarters. Other sectors such as business services and transport & communication react positively to a shock to foreign GDP but with a lag. The slow propagation of the shock is a sign that these sectors are probably influenced by second-round effects due to input-output linkages.

While these results are in line with the expectations based on export shares, this is less the case for the response of the banking sector. A shock to foreign GDP has a negative impact on this sector. The negative response sets in two quarters after the shock. This result, though surprising at first sight, can be explained by the sharp rise in interest rates which follows a shock to foreign GDP and counterbalances the positive effect of an increase in international growth. Indeed, as we show in section 4.3.3, banking responds strongly negatively to a rise in interest rates. The negative reaction in construction and in services to households implies that in these sectors, too, the increase in interest rates has a more powerful impact on value added than the rise in foreign GDP.

Figure 6: Cumulative impact of a shock to foreign GDP on sectoral value added



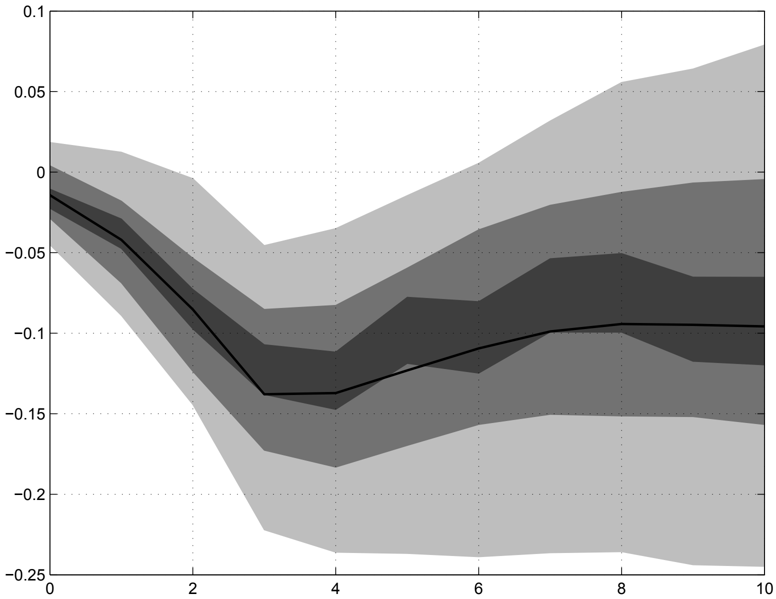
Note: median (line) and 20%, 50% and 80%-HPD intervals of the responses in % to a shock increasing foreign GDP by 1%

4.3.2 Impact of a shock to the exchange rate

The international economy not only affects the Swiss economy through changes in foreign GDP but also through the exchange rate. Indeed, an exchange rate shock, measured as a nominal appreciation of the Swiss franc with respect to export-weighted foreign currencies, has a considerable impact on Swiss growth. A 1% shock to the exchange rate leads to a cumulative negative change in aggregate GDP of 0.15% after three quarters.

The impact on aggregate GDP is less strong than the impact of a shock to foreign GDP. However, the standard deviation of changes in the exchange rate is about three times higher than that of foreign GDP growth. Therefore, a change in foreign GDP of the magnitude of a standard deviation and a change in the exchange rate of the magnitude of a standard deviation both have roughly the same impact on Swiss GDP growth. Moreover, in contrast to a shock to foreign GDP, a shock to the exchange rate has a permanent effect. Note that the response is compatible with the results of Assenmacher-Wesche and Pesaran (2009) but only half as strong as the estimates of Abrahamsen and Simmons-Sueer (2011).[11]

Figure 7: Cumulative impact of an exchange rate shock (appreciation) on aggregate GDP

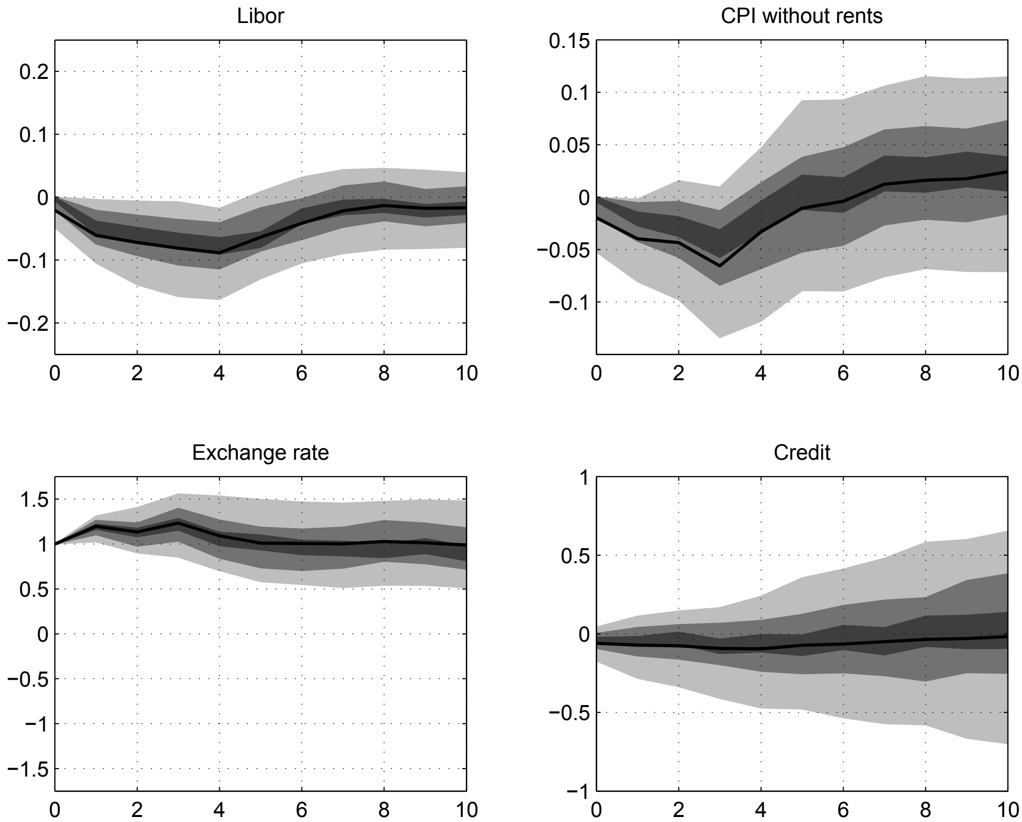


Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to a shock causing an appreciation by 1%

An exchange rate shock shifts the exchange rate permanently and leads to a rather persistent decrease in the CHF 3-month Libor. These results are depicted in Figure 8. The response of the short-run interest rates is in line with other studies, e.g. Bäurle and Menz (2008). The pass-through of between 0% and 10% to consumer prices is somewhat low, but still within the range found by other studies (see e.g. Stulz (2007)).

[11] See Appendix 6.5 for an overview of results from previous studies.

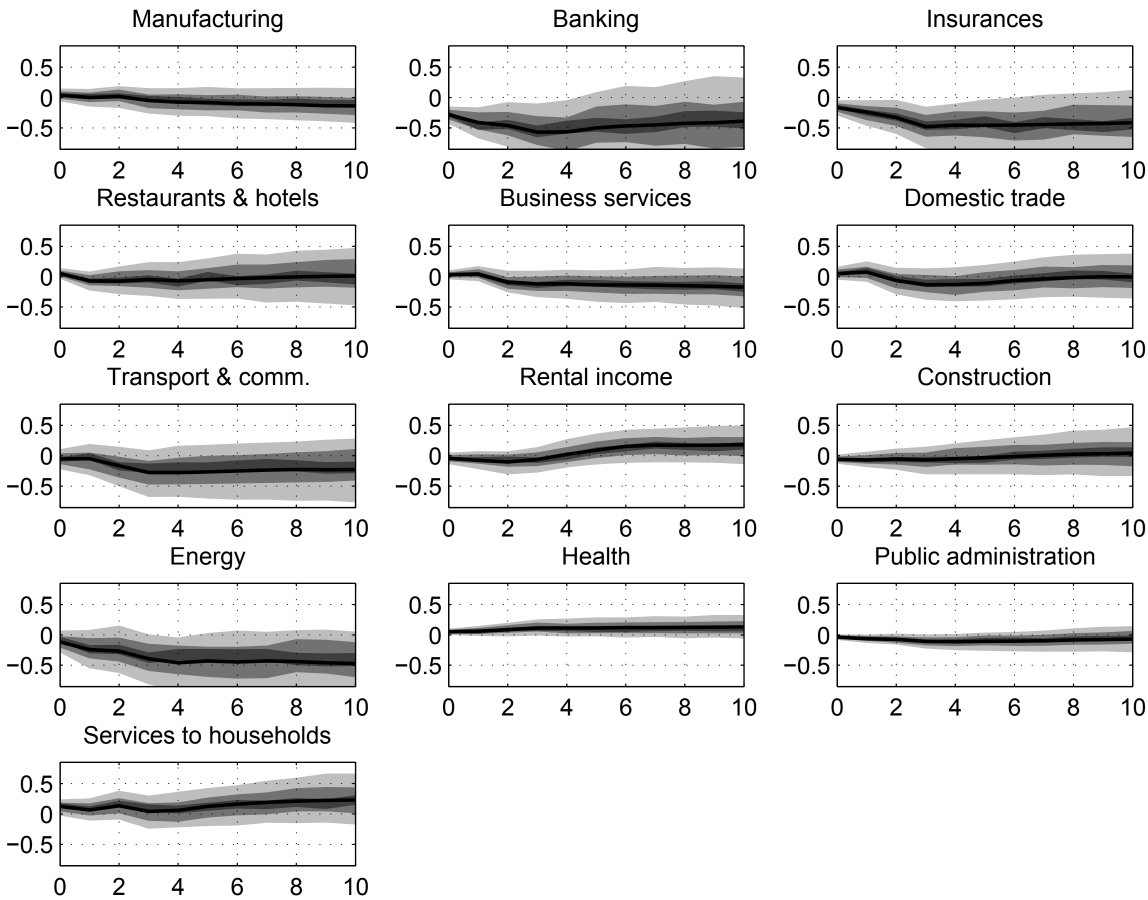
Figure 8: Cumulative impact of an exchange rate shock (appreciation) on common factors



Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to a shock causing an appreciation by 1%

The sectoral impulse response functions reveal that the response of value added to an exchange rate shock is quite heterogenous across sectors. This is shown in Figure 9. The financial sectors (banking and insurances) and the energy sector react sensitively to an appreciation, with their value added dropping by about 6% (banking) and 4% (insurances, energy) over the first year following the shock. The manufacturing sector is also hit by an appreciation but somewhat less strongly (cumulative 1% after one year) and with a lag. The lag may be explained by the fact that in the short run sale prices in the manufacturing sector are fixed by contracts. Moreover, one can assume that in the manufacturing sector cheaper imports counterbalance part of the negative effect of the appreciation on exports. Other sectors such as business services and transport & communication react negatively and permanently to an exchange rate shock. Through input-output linkages, these sectors are influenced by second-round effects. Domestic trade and restaurants & hotels react mildly and not permanently to an exchange rate shock. The restaurants & hotels sector is in itself very heterogeneous. The exchange rate probably has a large impact on the export oriented part of the sector. Indeed Abrahamsen and Simmons-Süer (2011) find that foreign overnight stays react with an elasticity of 1% to 2% with respect to the exchange rate. However, the export oriented part of the sector only accounts only about 20% of the whole sector. The larger part of the sector is domestic oriented (restaurants, canteens, catering, overnight stays of domestic guests). The exchange rate pass-through on the whole sector is therefore much weaker. Some domestic oriented sectors (eg rental services, services to households) show a positive reaction. An explanation is that the positive reaction is due to positive second-round effects emerging from the decrease in the CHF 3-month Libor.

Figure 9: Cumulative impact of an exchange rate shock (appreciation) on sectoral value added

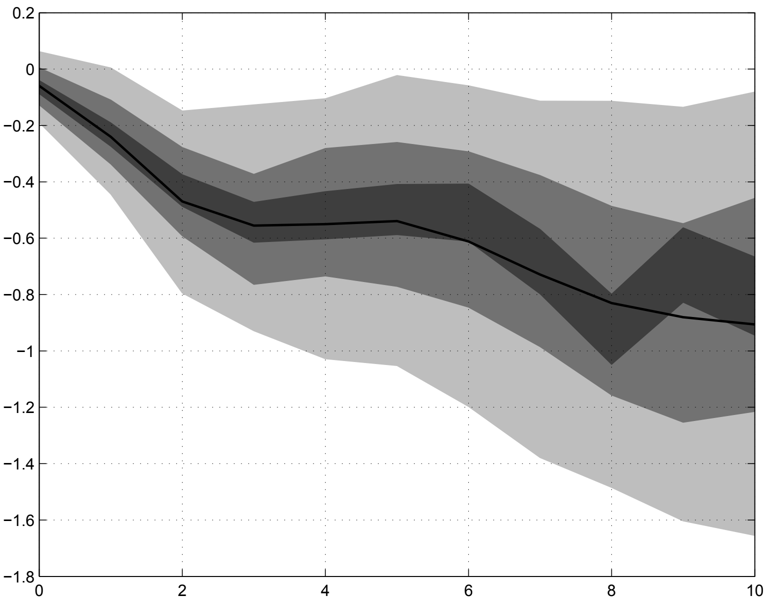


Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to a shock causing an appreciation by 1%

4.3.3 Impact of a monetary policy shock

Our results suggest that monetary policy shocks have a strong and persistent real effect and that this effect is mainly due to sectors which are closely linked to the financial markets. In Figure 10, the reaction of aggregate GDP to an interest shock is shown. An increase in the CHF 3-month Libor by 1 percentage point translates into a cumulative decrease in GDP by around 1% after two years. The pass-through to the real economy proceeds sluggishly. These results are coherent with the results of Jordan and Kugler (2004), Natal (2004) and Assenmacher-Wesche (2008). In contrast to the studies that preclude a contemporaneous reaction of GDP by assumption, we find an immediate negative reaction.

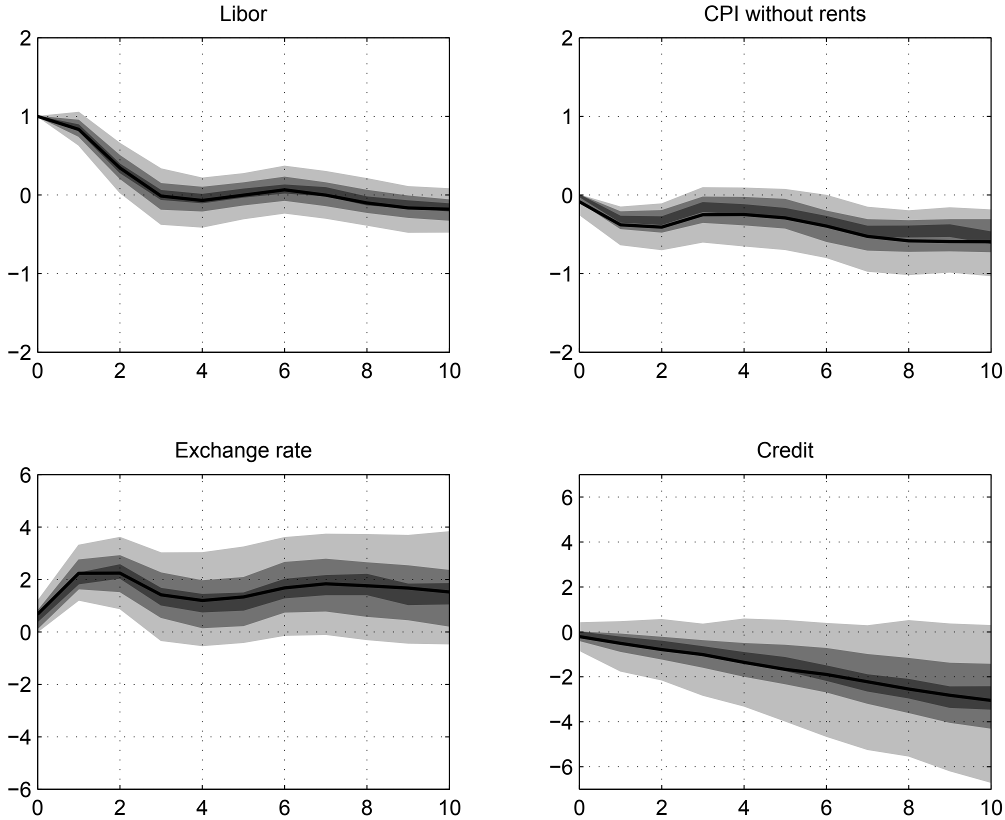
Figure 10: Cumulative impact of an interest rate shock on aggregate GDP



Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to an increase in the domestic interest rate by 100 basis points.

Further, the results in Figure 11 show that shocks to the CHF 3-month Libor have immediate repercussions on the exchange rate, consumer prices and the credit volume. Therefore, these variables cannot be treated as exogenous if they jointly enter an equation, such as a Taylor rule. Interestingly, our results indicate that the effect of monetary policy is permanent.

Figure 11: Cumulative impact of an interest rate shock on common factors

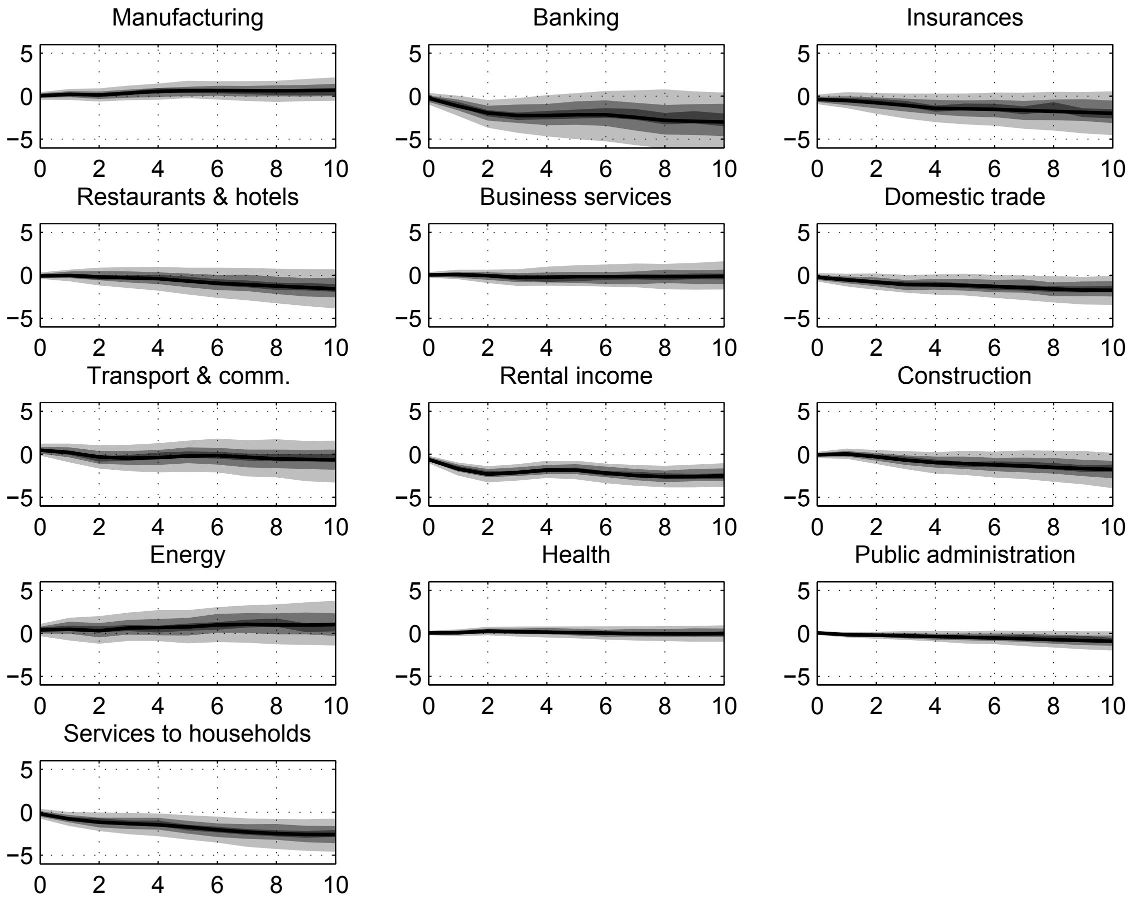


Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to an increase in the domestic interest rate by 100 basis points

The sectoral results show that the reaction to a monetary policy shock is also not uniform across sectors. In Figure 12, the sectoral responses to an interest rate shock of 1 percent point are shown. The strongest impact is visible in the financial sectors (banking and insurances). Rental services are also influenced strongly and persistently. This is probably because value added in this sector is directly dependent on interest rates. The construction sector reacts only very slowly. This is in line with the results of Steiner (2010), documenting a slow adjustment process of construction investment. Furthermore, contractionary interest rate shocks have a negative influence on some other sectors (domestic trade, services to households, transport & communication and restaurants & hotels). The negative reaction could be due to both a direct effect of tightening credit conditions and spillovers from sectors that are directly exposed to financial shocks. The two sectors driven by political decisions, health and public administration, are left practically unaffected by the interest shock.

Surprisingly, the manufacturing sector also shows no negative reaction to changes in interest rates.

Figure 12: Cumulative impact of an interest rate shock on sectoral value added



Note: median (line) and 20%, 50% and 80%-HPD intervals of the response in % to an increase in the domestic interest rate by 100 basis points

4.4 Robustness tests

We tested whether the results are robust with respect to the various assumptions made with respect to the data selection and model specifications described in section 3.2.

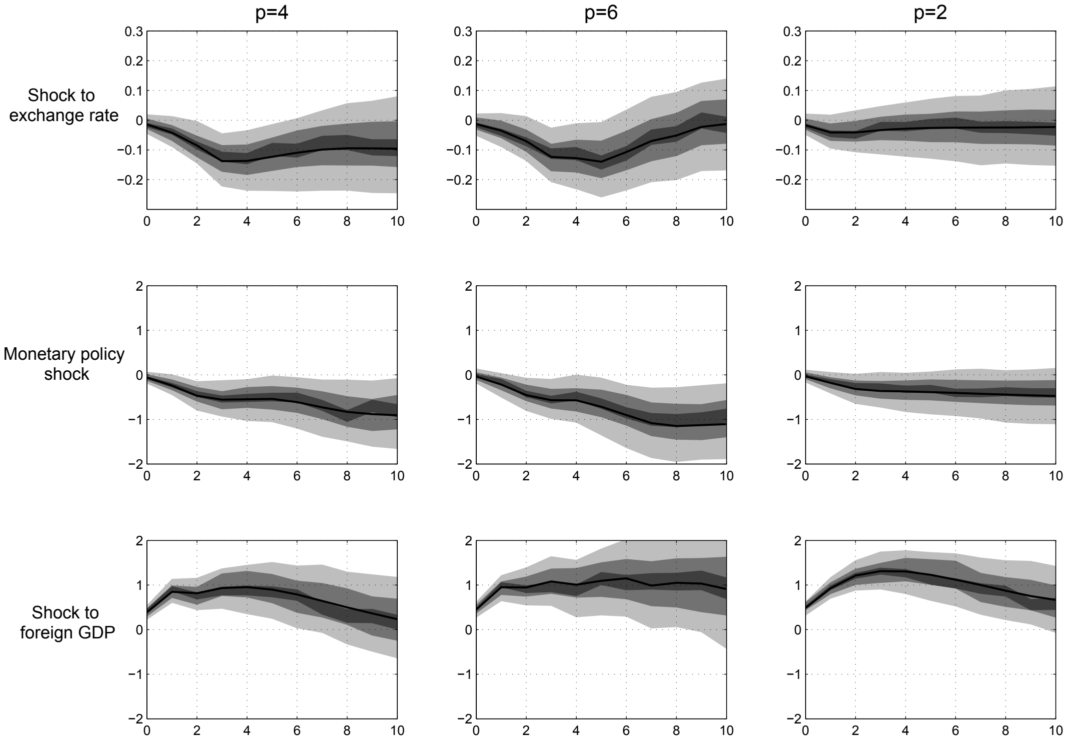
Data selection: First we tested the robustness of the model when other variables, such as Swiss M2, oil prices, stock prices and population were added. The inclusion of these variables has no relevant effect on the results we have discussed so far. For this reason, we decided to exclude them from our baseline specification.

Data transformation: The model uses quarter to quarter growth rates of the sector-specific, seasonally adjusted real value added. Given that in most of the series a seasonal variation is observed, one could also use log differences to the same period of the previous year of the non-seasonally adjusted series. It turns out that the results using this transformation are similar. Further, we used log deviations from a HP trend. In the short run, the results are comparable. However, as the HP trend captures much of the persistence, the responses converge quickly towards zero. This is evidence that the HP trend itself reacts to our identified shocks, such that we prefer not to extract the trend ex ante.

Number of unobserved factors: In section 3.2.3 we described the procedure employed to determine the number of unobserved factors and came to the conclusion that our model is optimally specified using one single unobserved factor. All the same, we checked the robustness of the model results by increasing the number of unobserved factors. As expected, the fraction of variance explained by common factors increases with an additional unobserved factor. However, the gain is very modest (in the magnitude of 5%). Furthermore, it turns out that the response of sectors to the identified shocks is hardly influenced. This confirms our a priori assessment that one unobserved factor captures the common dynamics sufficiently.

Number of lags: The model is specified with a lag length $p = 4$. We conducted robustness tests with a longer and a shorter lag length. First, we increased the number of lags to $p = 6$. Again, the results turn out to be robust, see Figure 13. Only at the end of the horizon, after about two years, do some differences appear. While the effect of the shock to foreign GDP seems to be slightly more persistent, the effect of an exchange rate shocks dies out somewhat more quickly. However, taking into account the uncertainty as measured by HPD intervals, the results are still closely in line with the baseline specification. On the other hand, decreasing the number of lags to $p = 2$ distorts some of the results. Some of the effects are much weaker, indicating that the reaction is not captured sufficiently with only two lags. These test results indicate that the number of lags should be set at $p = 4$ in order to obtain a parsimonious, but at the same time sufficiently flexible representation of the data.

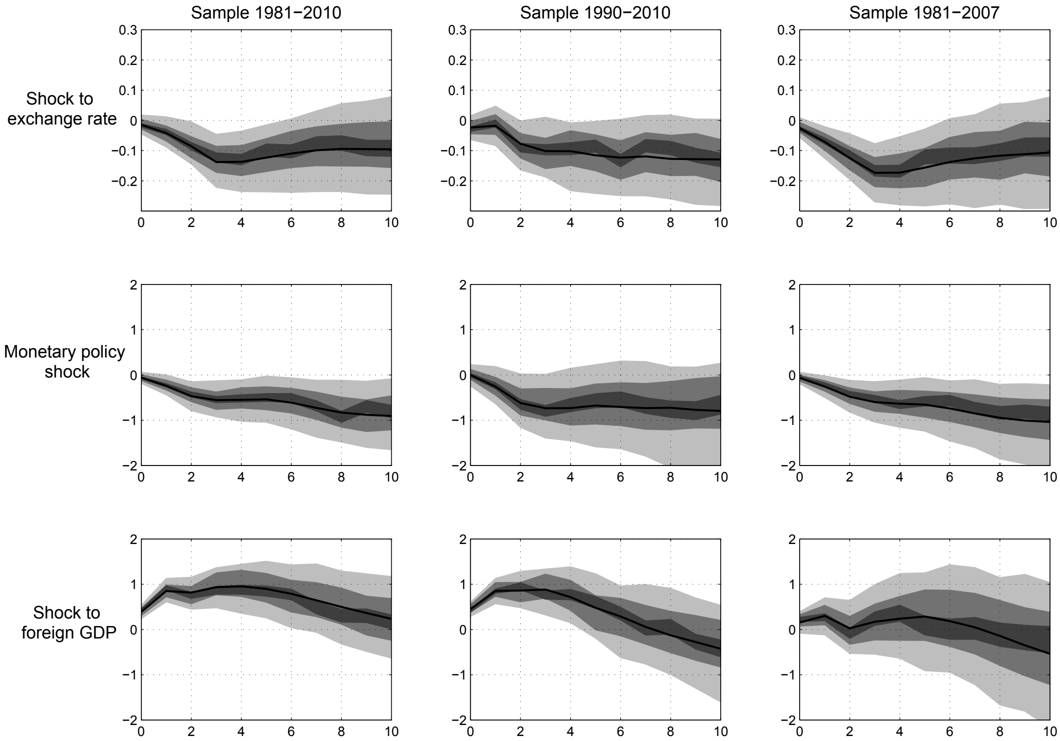
Figure 13: Cumulative impact of shocks on aggregate GDP for varying lag-length



Sub-samples: We estimated the model for different sub-samples. First, we excluded the 1980s to assess the importance of early observations as other studies document a structural change in Swiss data at the beginning of the 1990s (see Stulz (2007)). Second, we excluded the 'crisis period' from 2008 to 2010 to establish whether the results are driven by the rather extreme shocks during this period. The empirical results omitting the first part of the sample prove be comparable with the whole-sample results. Furthermore, the response of exchange rate and monetary policy shocks are stable using the sample excluding the 2008-2010 period.

The effect of a shock to foreign GDP, however, is affected by the omission of the 2008-2010 period in two ways: The median response of aggregate GDP is weaker and the HPD intervals are much larger (see Figure 14). This is an indication that the 2008-2010 period has a relevant role in pinning down precisely the effect of a foreign GDP shock and should therefore not be omitted. However, the instability of the median effect could also be a warning that some non-linear effects exist and, if the response to the shock increases more than proportionally with the size of the shock, our model with constant coefficients may be misspecified. The change in response could also indicate a structural break at the end of the sample. Nonetheless, until we have sufficient post-crisis observations it is practically impossible to disentangle non-linearities (when the change in the coefficient is temporary, caused by the large shocks during the crisis, and will be eventually reversed) from a structural break (when there is a permanent change in the coefficients). The finding of an unstable reaction to innovations in foreign GDP during the period from 2008 to 2010 calls for further investigations. These are, however, beyond the scope of this paper.

Figure 14: Cumulative impact of shocks on aggregate GDP for different samples



5 Conclusion

This paper uses the information contained in sector-specific value added data to measure the impact of common shocks on the real economy.

The analysis is done in the framework of a structural dynamic factor model because this allows us to describe the rather complicated dynamics of many observed variables without having to estimate an excessively large number of parameters. The sectoral series load contemporaneously on the common factors as well as on their lags. Thus, it is possible to model asynchronous responses to shocks. Furthermore, we identified shocks by combining standard zero restrictions with a sign-restriction approach.

The model includes the macroeconomic factors, which proved to be the most relevant for the Swiss economy. The international economy is proxied by three variables: foreign GDP growth, changes in the exchange rate, and foreign short-term interest rates. Domestic common factors are the CHF short-term interest rate, consumer prices, and the credit volume. Besides, we have included one unobserved common factor.

Owing to the incomplete and complex pass-through of common shocks to the Swiss economy, an analysis at a disaggregated level provides a more precise understanding of how the economy works. Summed up, the main insights from our analysis are:

- The variance decomposition shows that, in the short run, a sizeable part of the Swiss business cycle can only be explained by idiosyncratic shocks. This is why short-run fluctuations cannot be captured by a few variables at the aggregate level. The explanatory power of the common factors is substantial only after two to three quarters following a shock and reaches 53% at a 16-quarter horizon.
- Based on the impulse response functions for aggregate GDP, we conclude that shocks to foreign activity, the exchange rate and monetary policy have a considerable influence on the Swiss economy. A 1% increase in foreign GDP growth translates into an increase in aggregate GDP of 0.4%. A 1% appreciation in the exchange rate leads to a cumulative negative change in GDP of 0.15%. An increase in the CHF Libor by 1 percentage point leads to a cumulative decrease in GDP of around 0.8%.
- The impulse-response functions at the sectoral level show that the various sectors react heterogeneously to shocks. While certain sectors such as manufacturing, banking, insurances and restaurants & hotels react rapidly and markedly to

common shocks, others show a less pronounced and lagged reaction, for example the business service sector and the retail & wholesale trade sector. While our model is silent on the exact channel of transmission of shocks to these sectors, it is plausible that they are affected indirectly through spillovers. Finally, there remains a group of sectors which do not systematically react to shocks or in some cases even move against the cycle.

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6 Appendix

6.1 Data sources

Table 4: Data sources

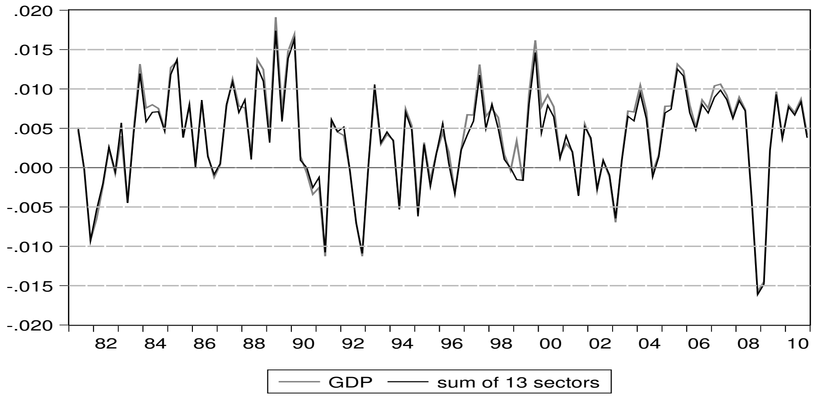
Variable	Description	Source
GDP and sub-sectors	value added, chained values at 2000 prices, seasonally adjusted	State Secretariat for Economic Affairs
Domestic interest rates	3-month CHF Libor	Swiss National Bank
Foreign interest rates	3-month German FIBOR until end 1998, 3-month EURIBOR from 1999 onwards	OECD
Foreign GDP	Export weighted foreign GDP of 22 major trading partners (DE, FR, UK, other EU-15, US, JP, CN, KR, HK, SG, TW), own calculations	Various national statistic offices
Exchange rate	Effective exchange rate with respect to 40 major trading partners, export-weighted, CPI based, own calculations	Swiss National Bank
CPI excluding rents	Consumer price index excluding the 'rents' sub-index, own calculations	Swiss Federal Statistic Office
Credits	Total domestic credits. Until 1997 annual data, own quartilization. Since 1987 monthly data	Swiss National Bank

6.2 Choice of sectors

Quarterly real value added data for Switzerland is available for 16 sectors. These 16 sectors together with taxes and subsidies on products aggregate to total GDP. For our analysis, we have omitted the very small sectors which had a weight in GDP of under 2% in 2010. The three omitted sectors (agriculture, mining and education) amounted in 2010 to 1.7% of GDP, taxes and subsidies on products to 6.6% (see Table 5). The exclusion of these sectors has practically no impact on the dynamics of total GDP. This is shown in Figure 15, which depicts the business cycle component of GDP and the sum of the 13 sectors included in our study.

Figure 16 shows that when the thirteen sectors are equally weighted over the whole

Figure 15: GDP and the sum of the 13 sectors analyzed (in log changes) 1981Q2 - 2010Q4



sample there are certain divergences compared to the quarter on quarter growth rates of GDP but that both series show similar dynamics. This implies that the size of the sectors is not very important in an analysis using quarter-on-quarter growth rates.

Figure 16: GDP and sum of the 13 sectors weighted equally over the whole sample (in log-changes) 1981Q2 - 2010Q4

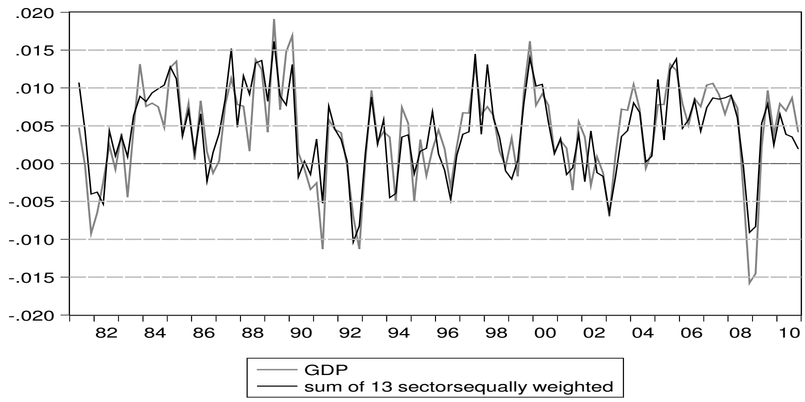


Table 5 shows the decomposition of Swiss GDP by sectors. SFSO publishes annual value added data for all sectors in the sixth column onwards. Seco provides quarterly figures only for the sub-aggregates listed in the first four columns.

Table 5: Sectors and sub-sectors of Swiss GDP

Sector name used in paper	Abbrev. used in paper	2008, CHF m	Share of GDP	SFSO sub-sectors, full name	SFSO codification	2008, CHF m	Share of GDP
Manufacturing	Manuf	103,430	19.0%		15-37		
				Manufacture of food products, beverages and tobacco	15-16	9,203	1.7%
				Manufacture of textiles	17	1,085	0.2%
				Manufacture of wearing apparel, dressing and dyeing of fur	18	409	0.1%
				Leather and footwear	19	151	0.0%
				Manufacture of wood	20	3,565	0.7%
				Manufacture of pulp and paper	21	1,679	0.3%
				Publishing, printing	22	4'938	0.9%
				Manufacture of coke, chemical industry	23-24	21,163	3.9%
				Manufacture of rubber and plastic products	25	3,192	0.6%
				Manufacture of other non-metallic mineral products	26	2,368	0.4%
				Manufacture of basics metal	27	2,186	0.4%
				Manufacture of fabricated metal products	28	10,074	1.8%
				Manufacture of machinery and equipment	29	13,877	2.5%
				Manufacture of office and electrical machinery and computers	30-31	4,602	0.8%
				Manufacture of communication equipment	32	3,589	0.7%
				Manufacture of medical and optical instruments, watches	33	16,006	2.9%
				Manufacture of motor vehicles	34	682	0.1%
				Manufacture of other transport equipment	35	1,537	0.3%
				Manufacture of furniture, manufacturing	36	2,544	0.5%
				Recycling	37	580	0.1%
Banking	Bnk	41,342	7.6%	Financial intermediation	65		
Insurances	Insur	23,592	4.3%	Insurance and pension funding	66		
Restaurants & hotels	RstrHtl	11,870	2.2%	Hotels and restaurants	55		
Business services	BusServ	56,640	10.4%		70-73		
				Real estate	70	5,612	1.0%
				Other business activities	71+74	38,984	7.2%
				IT	72	9,502	1.7%
				Research and development	73	2,542	0.5%
Domestic trade	DomTrade	69,921	12.8%		50-52		
				Sale, maintenance and repair of motor vehicles	50	7,609	1.4%
				Wholesale and retail trade	51-52	62,312	11.4%
Transport &comm.	TransCom	31,912	5.9%		60-64		
				Transport	60-62	12,626	2.3%
				Auxiliary transport activities, travel agencies	63	5,605	1.0%
				Post and telecommunications	64	13,681	2.5%
Rental income	Rent	30,414	5.6%	Rental income of private households	96-97		
Construction	Const	27,810	5.1%	Construction	45		
Energy	Energ	10,087	1.9%	Electricity, gas, steam and distribution of water	40-41		
Health	Hlth	31,922	5.9%	Health and social work	85		
Public administration	Admin	52,767	9.7%	Public administration, public social insurance	75		
Services to households	HhServ	12,464	2.3%		90-95		
				Sewage and refuse disposal, sanitation and similar activities	90	1,038	0.2%
				Recreational, cultural and sporting activities	91-92	6,885	1.3%
				Private households with employed persons, other service act.	93-95	4,541	0.8%
not included Sectors	Notincluded	40,856	7.5%				
				Agriculture, hunting, forestry, fishing and fish farming	1-5	6,460	1.2%
				Mining and quarrying	10-14	792	0.1%
				Education	80	2,731	0.5%
				Taxes on products		33,817	6.2%
				Subsidies on products		-2,944	-0.5%
Gross domestic Product	GDP	545,028	100.0%				

The following two figures depict the thirteen sectoral value added series and the six macroeconomic variables used in the model.

Figure 17: The 13 sectors analyzed and GDP (in log changes) 1981.Q2 - 2010.Q4

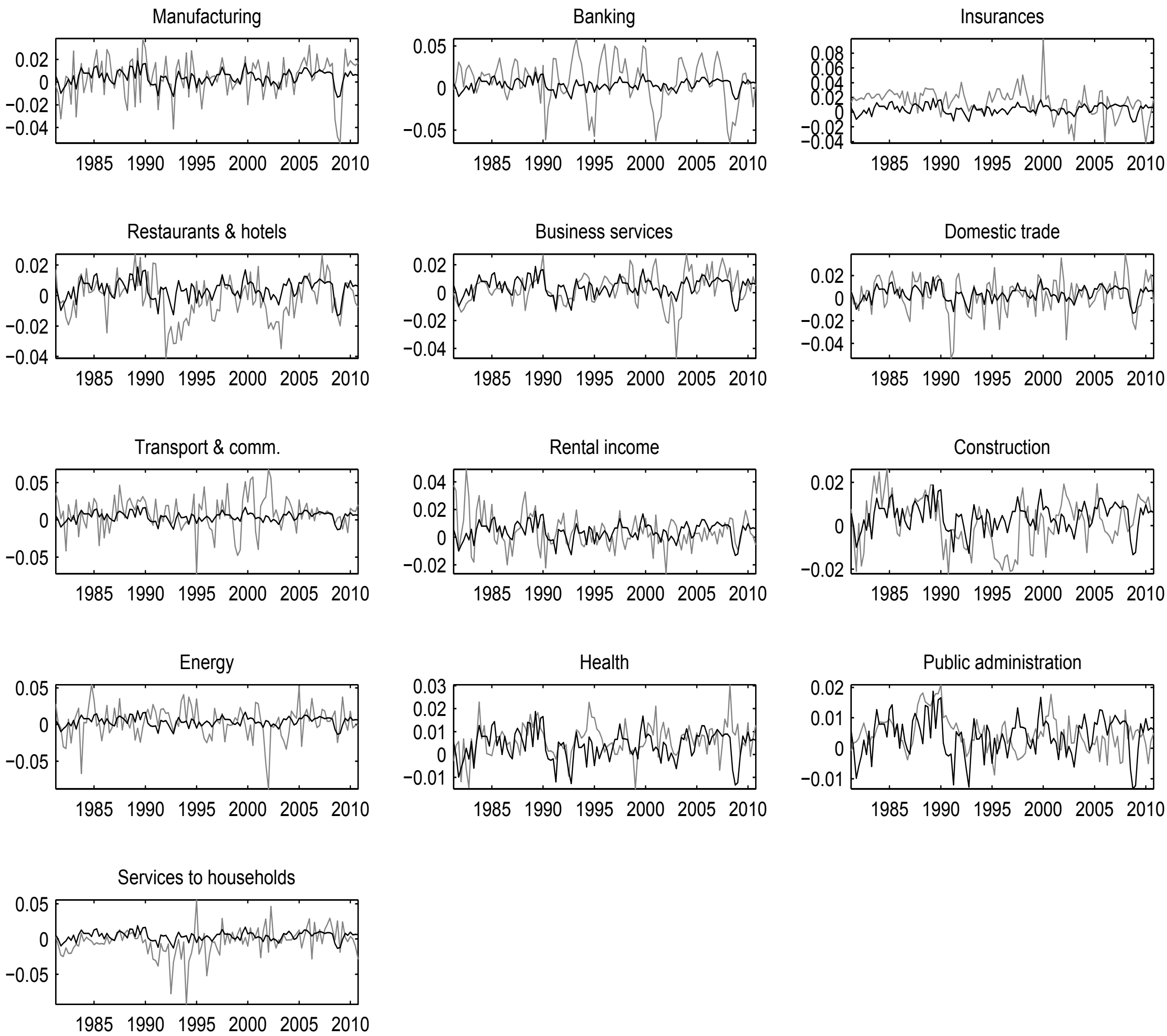
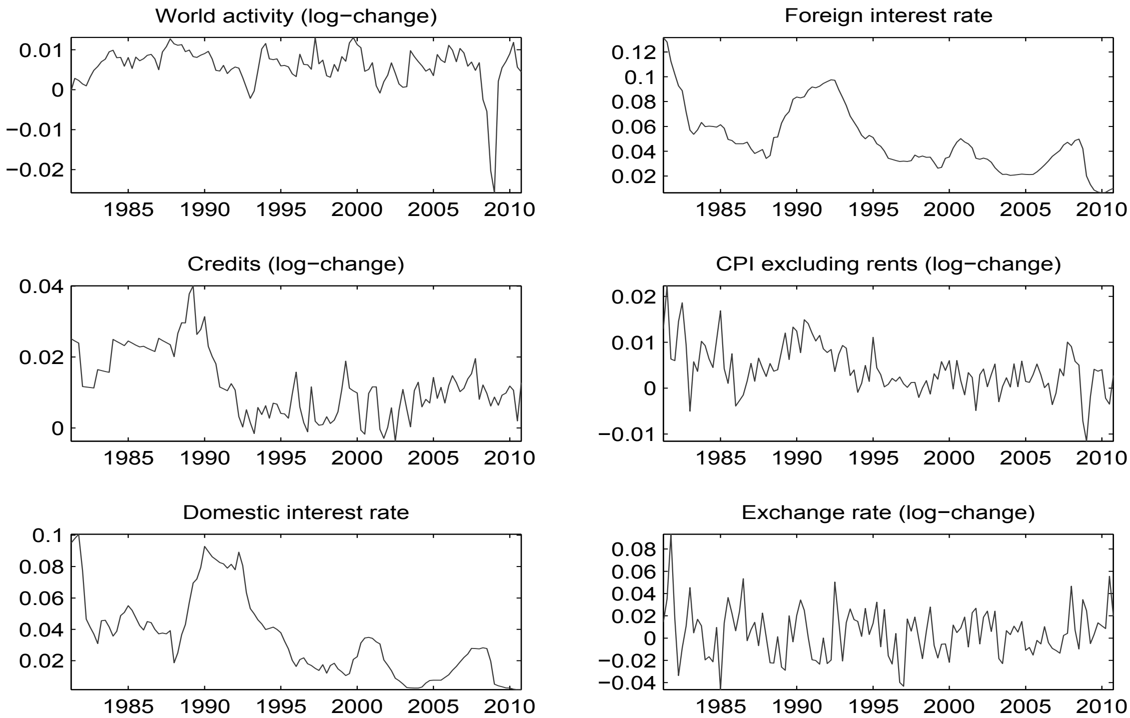


Figure 18: Macroeconomic variables entering the model 1981.Q2 - 2010.Q4



6.3 Static form of the dynamic factor model

Let us recall that the dynamic form of our factor model is (see Section 3.1)

$$\begin{pmatrix} X_t^S \\ X_t^M \end{pmatrix} = \begin{pmatrix} \lambda(L) & \\ 0 & I_{N^M} \end{pmatrix} \begin{pmatrix} f_t^S \\ f_t^M \end{pmatrix} + \begin{pmatrix} v_t \\ 0_{N^M \times N^S} \end{pmatrix} \tag{4}$$

where we have added, for notational convenience, the definition $X_t^M = f_t^M$ to the system. The observed variables load on the common factors and their lags with $\lambda(L) = \lambda_1 + \lambda_2 L + \lambda_3 L^2 + \ldots + \lambda_p L^{p-1}$. The following state equation describes the dynamics of the common factors:

$$\phi(L) \begin{pmatrix} f_t^S \\ f_t^M \end{pmatrix} = Q\varepsilon_t$$

This model can be rewritten in static form:

$$X_t = \Lambda F_t + V_t$$

$$F_t = \Phi F_{t-1} + \Upsilon_t$$

$$v_t = \Psi v_{t-1} + \xi_t$$

with

$$X_t = \begin{pmatrix} X_t^S \\ X_t^M \end{pmatrix}, F_t = \begin{pmatrix} f_t^S \\ f_t^M \\ f_{t-1}^S \\ f_{t-1}^M \\ \vdots \\ f_{t-p+1}^S \\ f_{t-p+1}^M \end{pmatrix}, V_t = \begin{pmatrix} v_t \\ 0_{q^S \times 1} \end{pmatrix}, \Upsilon_t = \begin{pmatrix} Q\varepsilon_t \\ 0_{(p-1)q\times 1} \end{pmatrix}$$

$$\Lambda = \begin{pmatrix} \lambda_1 & & \lambda_2 & \cdots & \lambda_p \\ 0_{q^M \times q^S} & I_{q^M} & 0_{q\times q} & \cdots & 0_{q\times q} \end{pmatrix}, \Phi = \begin{pmatrix} \phi_1 & \phi_2 & \cdots & \phi_{p-1} & \phi_p \\ I_q & 0_{q\times q} & \cdots & 0_{q\times q} & 0_{q\times q} \\ 0_{q\times q} & I_q & \dots & 0_{q\times q} & 0_{q\times q} \\ \vdots & \vdots & \ddots & 0_{q\times q} & 0_{q\times q} \\ 0_{q\times q} & 0_{q\times q} & \cdots & I_q & 0_{q\times q} \end{pmatrix}$$

$$Var(V_t) = R^{static} = \begin{pmatrix} R & 0_{N^S \times q^M} \\ 0_{q^M \times N^S} & 0_{q^M \times q^M} \end{pmatrix}$$

$$Var(\Upsilon_t) = \Sigma^{static} = \begin{pmatrix} QQ' & 0_{q\times(p-1)q} \\ 0_{(p-1)q\times q} & 0_{(p-1)q\times(p-1)q} \end{pmatrix}$$

This form is static in the sense that the states F_t and v_t contain all the information on X_t. Note that v_t could also be added to the state vector F_t.

6.4 Detailed model description and estimation method

In this section, we provide a description of the estimation method of the following state space system. Section 6.3 in this Appendix shows how to cast our dynamic factor model into this static form.

Observation equation:

$$X_t = \Lambda F_t + v_t \tag{5}$$

State equation:

$$\Phi(L) F_t = e_t \tag{6}$$

where X_t is a potentially high dimensional vector of $n = 1, \ldots, N$ data series observed over $t = 1, \ldots, T$ time periods. The idiosyncratic component is allowed to be serially correlated:

$$v_t = \Psi v_{t-1} + u_t$$

F_t is a vector of unobserved dynamic factors, the states, whose dimension M is typically much smaller than N. Each variable in X_t loads at least on one factor. Λ is the $N \times M$ matrix of factor loadings. The factors F_t are related to their lagged values by $\Phi(L) = I - \Phi_1 L - \ldots - \Phi_p L^p$. The error processes are assumed to be Gaussian white noise:

$$\begin{pmatrix} u_t \\ e_t \end{pmatrix} \sim \text{iN} \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} R & 0 \\ 0 & \Sigma \end{bmatrix} \right)$$

R and Ψ are assumed to be diagonal, hence the idiosyncratic components are cross-sectionally uncorrelated. As described in Appendix 6.3, our dynamic factor model can be written in this form.

The above assumptions fully determine the distribution of the data given a specific set of parameters Λ,R,Ψ,Φ and Σ, that is, the likelihood of the system. 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.

6.4.1 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 as to be adapted for autoregressive errors and potentially co-linear states, see e.g. Anderson and Moore (1979) and Kim and Nelson (1999).

6.4.2 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 is 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, Lubrano, and Richard (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, Lubrano, and Richard (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 parametrize 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 $M_{0,n} = 1$ for all n, $s = 3$ and $\nu = 0.001$ following Boivin and Giannoni (2006). 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, Lubrano, and Richard (1999).

6.4.3 Drawing parameters in the state equation

We use an improper prior for the VAR coefficients. A certain complication arises because we impose zero restrictions on certain coefficients as the marginal posterior densities for Σ and $\Phi(L)$ cannot be calculated based on the standard formulas for unrestricted Bayesian VARs. However, 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, Lubrano, and Richard (1999)). Hence, we introduce this additional Gibbs-sampling step into our MCMC algorithm.

6.5 Overview of empirical results from previous studies

Table 6 summarizes the results of existing studies documenting the effects of various shocks on GDP. Unfortunately, most of these studies do not present their empiric results in tables, rather, the results are often depicted in charts and no precise numbers are listed. Thus, the figures in Table 6 are approximate numbers derived as precisely as possible from the charts. Additional imprecision is to be expected because we had to normalize the responses to a monetary policy shock of an identical size to make them comparable. As such, the numbers in Table 6 only crudely represent the actual estimates in the respective studies. Some studies report confidence intervals around their point estimates. From these estimates, we calculated ranges for the elasticities 'by inspection'. These ranges should not be interpreted as exact confidence intervals with a certain coverage probability, but as plausible values according to the estimates. Additionally, note that the exact definition of the exchange rate and also of foreign GDP differs across studies. Moreover, some studies consider the monetary policy shocks to have an effect on some monetary aggregates in the first place, with the interest rate reacting to changes in liquidity, while other studies directly relate monetary policy to changes in the interest rate. Hence, there are also conceptual differences between shocks in different studies. Nevertheless, the overview in Table 6 is useful in providing the approximate magnitudes of the effect of different shocks on Swiss GDP.

Table 6: Empirical impact of shocks on Swiss GDP

Response of output to shock to	Interest rate 100bp decrease	Exchange rate 1% depreciation	Foreign GDP 1% increase	Method
Jordan and Kugler (2004)	0-0.8% after 2 years			Structural VAR
Natal (2004)	0.6-3.4% after 2 years			Structural BVAR
Jordan, Kugler, Lenz, and Savioz (2005)	2% after 2 years			Structural VAR
Assenmacher-Wesche (2008)	0.2-0.4% after 2 years			Structural VAR
Assenmacher-Wesche and Pesaran (2009)	0-0.6%	0-0.4%	0.25-1%	Structural VAR
Abrahamsen and Simmons-Süer (2011)		0.3%		Simultaneous equations model
Cuche-Curti, Dellas, and Natal (2009)	1.2% after 1 year			Calibrated DSGE model
Cuche-Curti and Natal (2010)	2% after 1 year		0.4%	Calibrated DSGE model
Kugler and Rich (2002)	0.1-0.5%			Structural VAR

Interest rate: A number of studies document the effect of monetary policy shocks. The effect of a decrease in the interest rate by 100 basis points on the level of GDP is highly uncertain, ranging from close to 0% to more than 3% after two years. Overall, the impression is that the medium-term effect is positive but small. With regard to the dynamics, most of the studies find that the effect is not immediate, that is the maximum effect on growth occurs one to two years after the shock. Note, however, that in some studies an immediate reaction is excluded by assumption. In the very long term, whether an effect is present or not is partly driven by the identification of the shocks. In some studies, a long-term effect is excluded by assumption.

Changes in the exchange rate: The transmission of changes in the exchange rate on the real economy has been less thoroughly analyzed. We found only two studies investigating the effect of exchange rate shocks on aggregate GDP. Assenmacher-Wesche and Pesaran (2009) find an effect of around 2% on GDP after an initial exchange rate shock of 20%. However, uncertainty around this estimate is rather large, ranging from 0% to 4%. Furthermore, the model used by Assenmacher-Wesche and Pesaran (2009) does not identify structural shocks. Thus, it is not possible to interpret the results in a causal way. A second study, by Abrahamsen and Simmons-Süer (2011), finds an increase of 3% following a 10% shock. Unfortunately, their model - a traditional large-scale macroeconomic model - is not described in detail in their paper.

Foreign GDP: The effect of a change in foreign GDP on Swiss GDP has been analyzed in two papers. According to Assenmacher-Wesche and Pesaran (2009) a shock to foreign GDP leads to an increase in Swiss GDP ranging from 0.25% to 1%. The model of Cuche-Curti and Natal (2010) implies an elasticity of around 0.4.

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