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OESTERREICHISCHE NATIONALBANK

WORKING PAPER 33

**CORE INFLATION IN SELECTED  
EUROPEAN UNION COUNTRIES**

**CHRISTINE GARTNER and GERT D. WEHINGER**

**September 1998**

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## Editorial

In this Working Paper Christine Gartner and Gert Wehinger, economists in the Oesterreichische Nationalbank (Christine Gartner is currently working at the European Central Bank), calculate core inflation indicators for various European Union Countries. Using a structural vector-autoregression approach they identify core inflation as the inflation components driven by demand and, respectively, monetary shocks. Results are partly corroborated by other, similar studies, and they conclude that such a core inflation indicator could be helpful for monetary policy especially at the European level.

September 30, 1998

# Core Inflation in Selected European Union Countries \*

Christine Gartner <sup>\*)</sup>, Gert Wehinger <sup>\*)</sup>

September 1998

## Abstract

We calculate core inflation indicators for Austria, Belgium, Finland, France, Germany, Italy, the Netherlands, Sweden and the United Kingdom using two structural vector-autoregression (SVAR) models. In the first one we use output and prices to identify supply and demand shocks by long-run identifying restrictions, for the second one we add short-term nominal interest rates to capture effects of monetary disturbances. Core inflation is then defined as driven by demand and, respectively, monetary shocks. Comparing our results to other studies we conclude that the resulting core inflation indicator can be regarded as helpful for monetary policy.

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## 1 Introduction

The issue of how to measure inflation and, in particular, its underlying trend has attracted increasing attention in recent years. A major reason for this renewed interest is that a number of central banks, both inside and outside the European Union, have committed themselves to explicit quantitative inflation targets<sup>1</sup>. The assessment of deviations of current and expected inflation from the target requires taking volatile and temporary price influences into account. The issue of distinguishing transitory from persistent price movements is also relevant for countries aiming for price stability in other monetary policy frameworks than inflation targeting. Alternative inflation indicators, especially those of core or underlying inflation,<sup>2</sup> may cast light on the sustainability of a country's inflation performance.

An important limitation of commonly used inflation measures such as the Consumer Price Index (CPI) is their susceptibility to specific disturbances which are unrelated to the "pure" (or core) inflationary process. As a result, measured inflation may give a misleading picture of underlying price trends relevant for monetary policy.

The purpose of this study is to provide information on underlying price movements relevant for the single monetary policy of the ECB. For comparative reasons, we use a model-based approach to calculate core inflation indicators for selected European countries. The core inflation process is identified by means of a VAR (vector autoregression) technique that was first suggested by Quah/Vahey (1995). We use a modification of the original model along the lines specified by Blix (1995) and Dewachter/Lustig (1997) in order to split measured inflation into core and non-core components. The underlying inflation process is that component of measured price movements which is governed by demand shocks.

In view of the central role that price stability plays for the single monetary policy of the ECB alternative inflation indicators, especially those of core or underlying inflation, will play an important role as monetary policy indicators, independently of the specific choice of the monetary policy strategy by the ECB. Although this topic has been treated in some studies, Austria has never been included so far.

## 2 The Concept and Measurement of Underlying Inflation

Although the concept of underlying inflation is widely used in monetary policy analysis<sup>3</sup>, views differ about its precise definition.

Many papers<sup>4</sup> refer to Eckstein's (1981) definition of underlying or core inflation as the rate of price increases that would occur along the economy's long-term growth path. The core inflation rate is thus a steady-state concept and equivalent to the trend increase of

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<sup>1</sup> For a comprehensive survey see, e.g., Leiderman/Svensson (1995), Haldane (1995). More recent contributions include Debelle (1997) or Masson et al. (1997).

<sup>2</sup> We will use the terms "core inflation" and "underlying inflation" interchangeably.

<sup>3</sup> The interest in Austria in alternative inflation indicators is relatively new. As it is well known, the Oesterreichische Nationalbank (OeNB) follows an exchange rate target and thus gears its monetary policy to that of the anchor currency (among others, see Gartner, 1995, and Hochreiter/Winckler, 1995). The effectiveness of the monetary strategy is measured in terms of the degree of inflation convergence with Germany. Up to now measures of underlying inflation played only a limited role. As far as the OeNB is concerned it focused its attention on the headline inflation rate, the CPI changes being the inflation indicator, making additive adjustments for the contribution of specific indirect tax changes or seasonal food prices whenever relevant.

<sup>4</sup> Among others, see EMI (1995).

the price of aggregate supply. Alternatively, Parkin (1984) assumes that in the long-run equilibrium, factor prices for labour and capital fully reflect inflation expectations. In that case, core inflation is identical to expected inflation. In other words, core inflation measures price increases along a long-run vertical supply or Phillips curve.

As there is no single concept of what is understood by core inflation it is not surprising that views on how to measure it differ.

The standard approach has been to remove, in some ad hoc manner, the "unwanted" component, such as transitory noise, which has its sources in changing seasonal patterns, resource shocks, exchange rate changes, indirect tax changes or asynchronous price adjustments, or other distorting influences like weighting differences, quality changes, new goods or the substitution bias. The remainder is seen as a reliable estimate of the underlying inflation process.<sup>5</sup> Removing distorting, temporary or particularly volatile influences can be done either on a case-by-case basis or in a more structured way. This first group of procedures includes the zero-weighting technique and its variants.

More structural methods of calculating specific underlying inflation indicators, based on time-series analysis, include simple as well as more sophisticated smoothing techniques (trimmed mean method, Hodrick-Prescott filter, Kalman filter) and the VAR models based on the paper by Quah/Vahey (1995). Such model-based calculations allow an interpretation of core inflation which is based on economic principles. By contrast, in the case of ad hoc procedures such as zero-weighting and smoothing techniques, an interpretation based on economic theory runs the risk of being fallacious.

We decided to use a VAR approach similar to Quah/Vahey's for two reasons: Firstly, Fluch/Gartner (1997) suggest that mechanical procedures such as the zero-weighting approach have certain drawbacks for cross-country analysis. Their empirical results show that the trend of and deviations from headline inflation heavily depend on the definition used. In spite of harmonisation efforts initiated by the European Monetary Institute, concepts of calculating core inflation still differ markedly. Secondly, we are interested in a forward looking assessment of inflation performance. Forecasting is not possible with the zero-weighting procedure and possible only with certain restrictions using the smoothing technique, whereas a model-based approach enables to project historical structures into the future.

### 3 Identifying Core Inflation

The two approaches mentioned above (zero weighting and smoothing) remove, in some ad hoc manner, the "unwanted" components ("noise") of measured inflation. What remains ought to be a reliable estimate of the underlying inflation process. In their paper, Quah/Vahey (1995) argue that the conceptual mismatch between current methods for calculating inflation and economic theory is more than just a measurement error. Price indices such as the CPI measure the costs of, in particular, goods and services, while the economic notion of inflation is that of sustained increases in the general price level. As economic theory does not suggest a particular functional form of inflation, there is no justification for believing that core inflation is the result of some arbitrary smoothing procedure.

Consequently Quah/Vahey (1995) suggest an alternative technique that explicitly refers to an economic hypothesis. They define core inflation as that component of measured inflation that has no medium to long-run impact on real output. This definition is consis-

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<sup>5</sup> This approach has been used, i.a., in the United Kingdom, Sweden, and Finland, and was also suggested by the EMI.

tent with a vertical long-run Phillips curve interpretation of the co-movements in output and inflation. They then implement this definition as a restriction on a bivariate SVAR (structural vector autoregressive) model and use it to extract a measure of core inflation. Our identification scheme differs only slightly as we identify effects on prices instead of price changes, thus referring to, from a theoretical viewpoint, a standard aggregate demand/aggregate supply framework.<sup>6</sup>

### 3.1 Methodology

The identification scheme of Quah and Vahey's model is very similar to that of Blanchard/Quah (1989) and Shapiro/Watson (1988).

It follows the VAR tradition in methodology, employing impulse response analysis and variance decompositions. The identification of the shocks is based on a Choleski decomposition of a long-run parameter matrix and is therefore different from the short-run identification schemes of Bernanke (1986) and others.

The structural model of real GDP  $y$  and CPI  $p$  has the long-run solution form

$$y = f(\boldsymbol{\varepsilon}^s) \text{ and} \quad (1)$$

$$p = f(\boldsymbol{\varepsilon}^s, \boldsymbol{\varepsilon}^d). \quad (2)$$

We assume that the economy is hit by innovations given in the vector  $\boldsymbol{\varepsilon} = (\boldsymbol{\varepsilon}^s, \boldsymbol{\varepsilon}^d)'$ , which contains a supply shock  $\boldsymbol{\varepsilon}^s$  and a demand shock  $\boldsymbol{\varepsilon}^d$ . While supply shocks<sup>7</sup> may have permanent effects on both prices and output, demand shocks are defined to have no long-run effect on output, i.e. they are transitory with respect to real variables. We identify the core inflation process as that part of the increases in the CPI that has no long-run effects on output, i.e. price movements that are determined solely by shifts in the aggregate demand curve ("demand pull" inflation)<sup>8</sup>. We compute core inflation by simulations imposing paths of structural shocks as described in section 3.3.

We impose two kinds of restrictions on structural innovations. Firstly, both of the structural disturbances are assumed to be uncorrelated at all leads and lags and have unit variance. Secondly, demand shocks cannot have long-run effects on output. The long-run effects of demand disturbances on CPI are unconstrained. These restrictions are sufficient to uniquely identify both of the underlying disturbances as will be shown below.

### 3.2 Identifying Restrictions and Identification of the Model

Assume that a vector  $\Delta \mathbf{x}$  of (differenced) macroeconomic variables follows a covariance stationary process of the form

$$\Delta \mathbf{x}_t = \mathbf{C}(L)\mathbf{u}_t. \quad (3)$$

In our case  $\Delta \mathbf{x} = [\Delta y, \Delta p]'$ , with  $y$  the log of real domestic output (GDP) and  $p$  the log of prices (CPI), respectively.  $\mathbf{C}(L)$  is a lag polynomial where the  $\mathbf{C}$ 's are coefficient matrices

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<sup>6</sup> From an empirical viewpoint we refer to the fact that most price changes can be considered as (trend-)stationary. See also the data section below on this issue.

<sup>7</sup> Typical supply shocks are productivity changes, energy price shocks, taxes and price controls.

<sup>8</sup> The simple framework applied here could be extended in order to capture also, e.g., "cost-push" inflation effects by including other variables such as wages and other specific prices.



at the respective lags of the serially uncorrelated errors  $\mathbf{u}$ , where  $E(\mathbf{u} \mathbf{u}') = \Sigma$ . The first coefficient matrix of the polynomial,  $\mathbf{C}_0$ , is normalised to the identity matrix  $\mathbf{I}$ .

A reduced form and normalised moving average representation of that process is given by

$$\Delta \mathbf{x}_t = \mathbf{E}(L) \mathbf{e}_t, \quad (4)$$

with  $E(\mathbf{e} \mathbf{e}') = \mathbf{I}$  and the shocks uncorrelated across time and across variables.

Only the  $\mathbf{u}$ 's can be directly estimated from the VAR, the  $\mathbf{e}$ 's have to be calculated based on its moving average representation (3). As we have assumed  $\mathbf{C}_0 = \mathbf{I}$  and we have a linear relation between  $\mathbf{C}(L)$  and  $\mathbf{E}(L)$  we can write

$$\mathbf{u}_t = \mathbf{E}_0 \mathbf{e}_t. \quad (5)$$

The problem is then to find  $\mathbf{E}_0$  imposing  $k \times k$  restrictions, where  $k$  is the number of variables in the model and thus  $k \times k$  is the dimension of  $\mathbf{E}_0$ .

From  $\mathbf{e} \mathbf{e}' = \mathbf{I}$  and  $\mathbf{u} \mathbf{u}' = \Sigma$  we have with (5)

$$\Sigma = \mathbf{E}_0 \mathbf{E}_0'. \quad (6)$$

This factorisation yields  $\frac{k(k+1)}{2}$  non-linear restrictions, for the rest of  $\frac{k(k-1)}{2}$  restrictions we impose long-term neutrality properties for certain errors driving the respective variables. If we evaluate the polynomial matrices at  $L=1$ , where a matrix  $\mathbf{E}(1) = \mathbf{E}_0 + \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3 + \dots$ , we get the long-run impacts of errors on the variable vector  $\Delta \mathbf{x}$ , and, specifically,

$$\Delta^* \mathbf{x} = \begin{bmatrix} \Delta^* y \\ \Delta^* p \end{bmatrix} = \begin{bmatrix} E_{11}(1) & 0 \\ E_{21}(1) & E_{22}(1) \end{bmatrix} \begin{bmatrix} \varepsilon_s \\ \varepsilon_d \end{bmatrix}, \quad (7)$$

where  $\Delta^* \mathbf{x} = \lim_{t \rightarrow \infty} \mathbf{x}_t - \mathbf{x}_{t^*}$ .

As  $\mathbf{E}(1)$  is assumed to be lower triangular, we can use this fact to recover  $\mathbf{E}_0$  in the following way. Equating (3) and (4) at their long-run values we have

$$\mathbf{C}(1) \mathbf{u}_t = \mathbf{E}(1) \mathbf{e}_t. \quad (8)$$

With  $\mathbf{e} \mathbf{e}' = \mathbf{I}$  and  $\mathbf{u} \mathbf{u}' = \Sigma$  the matrix  $\mathbf{E}(1)$  can be derived from a Choleski decomposition of

$$\mathbf{C}(1) \Sigma \mathbf{C}(1)' = \mathbf{E}(1) \mathbf{E}(1)'. \quad (9)$$

From the values for  $\mathbf{C}(1)$ , which can be derived from the estimated VAR-parameters, and the variance-covariance matrix  $\Sigma$  we compute the Choleski factor  $\mathbf{E}(1)$  and can then recover  $\mathbf{E}_0$  as

$$\mathbf{E}_0 = \mathbf{C}(1)^{-1} \mathbf{E}(1). \quad (10)$$

The matrix  $\mathbf{E}_0$  can then be used in  $\mathbf{u}_t = \mathbf{E}_0 \mathbf{e}_t$  to compute the impact of structural shocks on the elements of  $\Delta \mathbf{x}_t$  (orthogonal impulse responses).

With this background, we proceed as follows for the empirical analysis. First we estimate a vector-autoregressive (VAR) model of the form

$$\mathbf{A}(L) \Delta \mathbf{x}_t = \mathbf{u}_t. \quad (11)$$

From  $\mathbf{A}(L)$  we compute (accumulate for) the long-run entries of  $\mathbf{A}(1)$ . Inverting yields  $\mathbf{A}(1)^{-1} = \mathbf{C}(1)$ . Consequently we get  $\mathbf{E}_0$  from (9) and (10), which we use to compute the respective impulse responses and the variance decomposition of the structural shocks given in (4).

### 3.3 Computing Core Inflation: Simulations Using Structural Shocks

Core inflation  $\pi^c$  is defined as that component of inflation which has no permanent effect on output. Thus we calculate core inflation based on structural shocks absent supply elements. The structural shocks  $\mathbf{e}_t$  are recovered from the estimated errors  $\mathbf{u}_t$  through the relation  $\mathbf{e}_t = \mathbf{E}_0^{-1}\mathbf{u}_t$ . Having found  $\mathbf{e}_t$  forecast simulations can be computed by dropping the supply element of the shock vector, i.e. we set  $\mathbf{e}_t^s = [0, \mathbf{e}_{D,t}]'$ . Then the errors  $\mathbf{u}_t^s$  to be used for the core inflation forecasts with the estimated VAR models will be recovered through  $\mathbf{u}_t^s = \mathbf{E}_0\mathbf{e}_t^s$ .

### 3.4 Interpretation

The first important assumption underlying this technique concerns the number of structural innovations. Quah/Vahey (1995) assume that there are only two types of shocks affecting inflation and output. In reality, the economy is hit by a large number of heterogeneous shocks, and each of them may have different effects on measured inflation and output. In line with the work of Blix (1995) and Dewachter/Lustig (1997), we explicitly address this potential misspecification problem by extending the SVAR and checking the robustness of the results. In the extension we distinguish between monetary and real aggregate demand shifts, since these may affect inflation and output differently.

The second debatable assumption is the orthogonality restriction on the structural innovations. Following the Quah/Vahey (1995) methodology we assume core and non-core innovations to be uncorrelated at all leads and lags. Nevertheless, some policy shifts in response to core shocks (for instance a restrictive or loose fiscal policy in response to a price hike) may have a permanent effect on output. As a result, non-core innovations may be caused by core innovations. The model, however, excludes the possibility of such correlations.

The identifying restrictions do not constrain the structural multipliers determining the response of measured inflation to non-core innovations, i.e. the long-run price effect is unrestricted. If non-core innovations explained a sizeable part of the long-run variability in measured inflation (as one could see from the variance decompositions below), the Quah/Vahey (1995) identification procedure would have to be re-examined. This would mean that mainly the non-core innovations drive the inflationary process.

### 3.5 Extension: Including Monetary Policy

To assess the restrictiveness of the two-shock approach outlined above, we extend the bivariate SVAR by introducing a monetary variable. This has been done before: Blix (1995) introduced monetary aggregates as a third variable. Dewachter/Lustig (1997), who are mainly interested in empirical results for the ERM-countries, include a short-term nominal interest rate in the model. As our (future) interest is in common trends in underlying inflation, we proceed along the lines of Dewachter/Lustig (1997) and also include short-term interest rates as the monetary policy variable. We implicitly assume that monetary

aggregates are endogeneous, which appears to be a fair assumption for most European countries.

We assume that a small open economy with a fixed exchange rate regime is hit by three structural innovations: a supply shock, a monetary shock and a demand shock, the latter two of which are core innovations. Hence, the structural model in real output  $y$ , short-term interest rates  $i$ , and CPI  $p$ , in its long-run representation has the form

$$y = f(\boldsymbol{\varepsilon}^s), \quad (12)$$

$$i = f(\boldsymbol{\varepsilon}^s, \boldsymbol{\varepsilon}^m), \text{ and} \quad (13)$$

$$p = f(\boldsymbol{\varepsilon}^s, \boldsymbol{\varepsilon}^m, \boldsymbol{\varepsilon}^d). \quad (14)$$

The non-core innovations  $\boldsymbol{\varepsilon}^s$  are interpreted as supply disturbances (e.g. technology shocks<sup>9</sup>), which generate relative price shifts. These supply shocks are assumed to have a permanent effect on output. As in the case before core inflation is defined as that component of measured inflation which is not affected by supply innovations.

The first type of core innovations  $\boldsymbol{\varepsilon}^m$  captures the effects of a monetary disturbance. These LM-innovations do not affect real output permanently, but they are supposed to exert a lasting influence on short-term nominal interest rates and on inflation. Given the validity of interest parity,  $i = i^* + \dot{e}$ <sup>10</sup>, in the long run, the  $\boldsymbol{\varepsilon}^m$  innovation can also be interpreted as an EU-wide (ERM-wide, see below) monetary policy shock. As for countries pursuing a fixed exchange rate regime it holds that  $\dot{e} \equiv 0$  in the long run, an exogenous shift in the level of  $i^*$  has to be accommodated by an permanent shift in  $i$ . In the short run, due to lower credibility of the peg,  $i$  can deviate from  $i^*$  to the extent of devaluation expectations.

Two major effects of nominal interest rate innovations can then be distinguished among countries of the European Monetary System (EMS): For (smaller) countries with a credible and tight exchange-rate peg (within the Exchange Rate Mechanism, ERM) an interest rate increase will arise mainly due to an accommodation of an increased ERM-wide interest rate level, and even short-run output and price effects should be very small. For countries allowing (or having allowed) for more flexibility in the exchange-rate peg (e.g., not having permanently participated in the ERM) a nominal interest-rate shock can, given the validity of the interest parity, also be interpreted as following an autonomous expansionary monetary disturbance, giving rise to devaluation expectations  $\dot{e}$ , increasing output at least temporarily (long-run effects are restricted to be zero) and prices even at longer time horizons.<sup>11</sup>

The second type of core innovations consists of a real demand shock. This AD- or IS-shift affects the rate of inflation in the short run and the price level in the long run, but leaves output and the interest rate level ( $i$ ) unchanged at an infinite horizon.

Consider a vector  $\Delta \mathbf{z}$  which now includes changes in the short-term nominal interest rate,  $\Delta i$ . This vector  $\Delta \mathbf{z}$  is a covariance-stationary process not constrained by a cointe-

<sup>9</sup> Cf. footnote 7, p.9.

<sup>10</sup> Where  $i$  denotes the domestic interest rate,  $i^*$  the foreign interest rate or that of the anchor currency country and  $\dot{e}$  is the expected change in the nominal exchange rate over time.

<sup>11</sup> In fact, as shown below, we find such behaviour of variables for Belgium, Finland, France, Italy, Sweden and the United Kingdom.

grating relation. This in turn means that it has an invertible moving average representation which, in its long-run (accumulated) form, is given by

$$\Delta^* z = \begin{bmatrix} \Delta^* y \\ \Delta^* i \\ \Delta^* p \end{bmatrix} = \begin{bmatrix} E_{11}(1) & 0 & 0 \\ E_{21}(1) & E_{22}(1) & 0 \\ E_{31}(1) & E_{32}(1) & E_{33}(1) \end{bmatrix} \begin{bmatrix} \varepsilon_S \\ \varepsilon_M \\ \varepsilon_D \end{bmatrix}, \quad (15)$$

where  $\Delta^* z = \lim_{t \rightarrow \infty} z_t - z_{t^*}$

As before,  $\varepsilon_S$  denotes the supply shock (i.e. non-core innovation) and  $\varepsilon_D$  is a real demand disturbance, additionally now  $\varepsilon_M$  represents the monetary shock. Note that the matrix of the structural multipliers in (15) is invertible. This system is fully identified. Core innovations are distinguished from non-core innovations by imposing that the latter cannot affect output in the long run. Money demand shocks are distinguished from real demand innovations by assuming that the latter have no lasting impact on interest rates.

### 3.6 Computing Core Inflation in the Extended Model

Like in section 3.3 we use the method of eliminating supply shocks to compute core inflation  $\pi^c$ , which in the trivariate model would be defined as the component of inflation driven only by real demand and monetary shocks, both of them having no permanent effect on output.

Having recovered  $\mathbf{e}_t$  from the estimated errors  $\mathbf{u}_t$  through the relation  $\mathbf{e}_t = \mathbf{E}_0^{-1} \mathbf{u}_t$ , we set  $\mathbf{e}_t^{S'} = [0, \mathbf{e}_{LM,t}, \mathbf{e}_{D,t}]'$ . Then, as before, the errors  $\mathbf{u}_t^{S'}$  to be used for the forecasts with the estimated VAR models are recovered through  $\mathbf{u}_t^{S'} = \mathbf{E}_0 \mathbf{e}_t^{S'}$ .

## 4 Estimation

We apply the identification technique outlined above to assess the performance of the CPI as a measure of "true" inflation. This is done by tracing the difference between measured inflation (using CPI) and (computed) core inflation using the mentioned bivariate and trivariate SVAR models. We estimate bi- and trivariate VAR systems in GDP growth, changes in prices and short-term nominal interest rates, respectively, for Austria, Belgium, Germany, Finland, France, Italy, the Netherlands, Sweden and the United Kingdom. The estimation period is 1971:1 to 1996:4. Values for 1997 and 1998 are forecasts from the estimated VAR models.

### 4.1 Data

We use quarterly, non-seasonally-adjusted data for the CPI (or a comparable price index such as cost of living or Retail Price Index - RPI) provided by OECD Main Economic Indicators. Quarterly GDP data and short term interest rates (3-months) are taken from the BIS data base. We subject the log levels of the data to a couple of tests such as the Hylleberg test<sup>12</sup>, the Augmented Dickey-Fuller<sup>13</sup> (ADF) as well as the Phillips-Perron<sup>14</sup> tests.

<sup>12</sup> Hylleberg et al. (1990) suggest a test for seasonal roots, as implied by our annual differencing of the data.

<sup>13</sup> See Dickey/Fuller (1979,1981).

<sup>14</sup> See Perron (1988) and Phillips/Perron (1988).

The Hylleberg test results suggest to take the fourth lag differences of the data, ADF and Phillips-Perron tests are then applied to these differences. The results are broadly consistent with output, prices and interest rates being integrated of order one. Hence, there is at least one shock for each variable affecting it permanently. Therefore, GDP, prices and interest rates enter the VAR system as year-on-year growth rates. Before entering the VAR, we deduct the respective means from changes in GDP and interest rates (i.e. the level series contain a trend). As the test results suggest year-on-year inflation rates to be trend-stationary, we adjust inflation rates for a trend variable, which could capture the impact of a "secular" downward trend in inflation which is observed in most countries.<sup>15</sup> Such a behaviour of inflation seems plausible, given the increase in competitive pressures, the on-going deregulation and integration of markets. At last, test results in general do not suggest cointegrating restrictions or error correction terms.<sup>16</sup>

## 4.2 Bivariate SVAR

As a first step bivariate VAR systems in GDP growth and changes in prices are estimated over the period 1971:4 to 1996:4 for all countries. We include three lags, supported by various information criteria.<sup>17</sup> Estimation results are reported in Figures 1 to 9. Both inflation measures, CPI and core inflation, are calculated as the log change in the price level with respect to the corresponding quarter of the previous year. Core inflation is estimated as specified in section 3.3.

### 4.2.1 Core versus CPI Inflation

Figure 1 displays the results for Austria. Overall CPI inflation seems to track the underlying rate of inflation. The peaks and troughs of both measures coincide more or less, yet the deviations tend to be very persistent. From 1971 to 1975 the underlying inflationary process was stronger than the conventional inflation measure would have suggested. After 1975 the opposite was true. Beginning with the late 1970ies up to 1987 CPI inflation was considerably higher than our measure of core inflation resulting mainly from the absence of positive supply shocks (productivity slowdown). In the late 1980ies, the Austrian economy was hit by a number of positive demand (core) shocks which led to an underlying inflation process considerably stronger than CPI inflation.

Estimation results for Belgium are shown in Figure 2. Again, core inflation closely follows actual inflation. We found a core inflation process that is in some periods considerable weaker than actual inflation. Especially, in the years around the first (1974) and the second oil price shock (1981) inflation was overestimated by the conventional inflation

<sup>15</sup> Many price series can be considered borderline cases between being I(1) and I(2) (integrated of order one or two, respectively). As we found I(1) evidence in many cases we treated even the borderline cases as such in order to provide a single framework for our analysis.

<sup>16</sup> Applying the Engle/Granger (1987) tests we could not find cointegrating relationships between the variables; applying Johansens (1991) procedure some of the cases look more ambiguous. However, adding error correction terms to the VAR then did not seem to alter the results significantly. Therefore and in order to keep the framework simple but still applicable to all countries we did not estimate the model in its vector-error correction form.

<sup>17</sup> Three information criteria were used to determine the lag length for the respective VAR estimation: the Akaike Information Criterion (AIC; Akaike, 1973), the Schwarz Information Criterion (SC; Schwarz, 1978; for both cf., e.g., Judge et al., 1988, p.870ff), and the Hannan/Quinn Information Criterion (HQ; Hannan/Quinn, 1979), using the simple formulae

$$AIC = \log|\Sigma| + \frac{2k}{T}, \quad SC = \log|\Sigma| + \frac{k \log T}{T}, \quad HQ = \log|\Sigma| + \frac{2k \log(\log T)}{T},$$

where  $|\Sigma|$  is the determinant of the variance-covariance matrix of the VAR residuals,  $k$  is the number of parameters in the model and  $T$  is the number of observations.

statistics. Also in the 1990ies core inflation is lower than actual inflation. After 1993, deviations of core from actual inflation diminish gradually due the absence of positive supply shocks. At the end of 1993, the "plan global" was implemented which included tax increases and programmes of wage moderation. Consequently, core shocks gained relative importance explaining the inflation process.

Estimation results for Finland can be seen in Figure 3. According to our calculations the Finnish case represents an exception. Very much like the British RPI, the Finnish CPI inflation seems hardly to be influenced by core innovations. Supply shocks tend to have had a massive impact on the Finnish inflation statistics. Deviations of the underlying inflation measure from the CPI inflation process are substantial. Massive positive deviations can be observed for the years around the first and the second oil price shocks. More recently the opening up of Eastern Europe had significant consequences for the Finnish economy. Negative supply shocks lead to an underlying inflation rate considerably lower than actual inflation. The danger of imported inflation due to a sharp depreciation of the markka was mitigated by incomes policy. In more recent years the core inflation indicator overestimated actual inflation (which could be a sign of an overheating economy).

The French inflation experience is illustrated in Figure 4. We find an underestimation of the underlying inflation by the conventional inflation statistics in the first part of the 1980ies, while in the second half of the decade inflation was underestimated by the CPI measure. For the 1990ies, we get a core inflation measure that is substantially below measured inflation. One explanation could be that the French economy, in the process of budget consolidation, was hit by a couple of supply shocks that are not captured by the core inflation measure.

Figure 5 considers the German case. As in the Austrian case, the calculated core inflation tracks the CPI inflation, i.e. the turning points coincide. The deviations of core inflation from CPI are not very large; with the exception of 1991 (German unification) they remain within the 1.5%-band over the whole sample.

The results for Italy are summarised in Figure 6. The differences between Italian CPI and core inflation are minor. This indicates that supply shocks have had only a very restricted impact on CPI inflation, which therefore was mainly demand driven.

Figure 7 shows the Dutch estimated core and CPI inflation. The assessment of our results for the Dutch inflation experience is very much the same as for Italy. Supply shocks seem to have only a minor impact on the inflationary process. The deviations of actual inflation from core inflation remain well within the 1% band. As for Italy, we have no clear-cut explanations for these empirical findings.

As can be seen from Figure 8, our calculations for the underlying inflation rate closely follow the CPI measure also in Sweden. At the beginning of the sample, the underlying inflation indicator ignores the ups and downs of the rather volatile CPI inflation rate. So we cannot give a clear statement whether the underlying inflation rate was definitely over- or underestimated by CPI inflation in the first part of the 1970ies. In the second part of the 1970ies, core inflation is overestimated by actual inflation. The picture changes at the beginning of the 1980ies: Deviations of CPI inflation from core inflation tend to be comparatively small in the 1980ies due to the absence of positive supply shocks. Negative supply shocks and a strong depreciation of the krona led to an actual inflation rate that substantially overestimated the underlying inflation rate. Beginning in 1994 price stability could be restored. In the following years the Swedish economy displayed low inflation rates,

hence it is not surprising that the calculated core inflation indicator is well above the measured CPI inflation.<sup>18</sup>

The results for the United Kingdom are reported in Figure 9. The calculated core inflation measure for the UK tends to be relatively smooth as compared to the actual inflation. This means that supply innovations seem to have an important impact on the measured inflation rate. As the UK is, apart from Norway, one of the major oil producing OECD countries, oil price shocks constitute an important (and positive) part of supply shocks leading to downward shifts of the price level. Consequently, actual inflation overestimates the underlying inflation trend for the respective periods. In the 1980ies the absence of positive supply shocks brings about an underlying inflation that lies considerably above the measured inflation rate (which could also be due to the influence of low oil prices, a non-core element of the inflation process). At the beginning of the 1990ies the calculated core inflation rate is very low and turns out to be negative for a few periods. Negative productivity shocks may have pushed RPI above core inflation. Towards the end of the sample, positive productivity shocks (increased flexibility of the labour market) may have put downward pressure on inflation by increasing the output potential and thus resulting in an underlying inflation lower than the usual inflation measure.<sup>19</sup>

We compared our findings with those of Bjørnland (1997), Blix (1995), Dewachter/Lustig (1997), Fase/Folkertsma (1997), Quah/Vahey (1995) and Jacquinot (1998), who used similar concepts. It is not surprising that their results sometimes differ markedly. We want to name only three possible reasons for these differences, which seem to be the most influencing factors. First, in contrast to other empirical studies on this topic, we did not use industrial output data as a proxy for overall output of the economy, but we applied real GDP<sup>20</sup>. Due to data availability, the second difference is a consequence of the first: we used quarterly instead of monthly data. The third source for the deviation clearly comes from the specification of the model. As we assumed the inflation rate to be (trend-)stationary, the change of prices instead of the change of the inflation rate enters the VAR system. The results are very sensitive to such differences in specification.

#### 4.2.2 Impulse Response Functions and Variance Decompositions

Figures 10, 14, 18, 22, 26, 30, 34, 38 and 42 report the estimated dynamic responses of measured inflation and output to a one percentage point (ppt.) supply (non-core) and demand (core) shock, for all countries and for the bivariate case. For our purposes the upper and lower right graphs of each figure are relevant.

The dynamic response of CPI inflation to supply disturbances differs substantially from its response to demand disturbances. The results for the impulse response functions very much coincide with what we would expect from theory. Let us consider a simple AS-AD (aggregate supply–aggregate demand) model. A positive productivity shock would shift the AS curve to the right. As a consequence, prices would decrease. This is exactly what we can see in the shape of the impulse response function of CPI on a one period one ppt. increase in aggregate supply. An initial downward jump in prices is followed by step-by-step decreases of prices until the inflation rate converges to zero and the new price level is found.

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<sup>18</sup> The results for this period are completely opposed to the observations by Blix (1995). He got a strong overestimation of the core inflation by the CPI measure. Thereafter the core inflation calculated by Blix shows a smoother development as it is the case with our calculations.

<sup>19</sup> By visual inspection, we find that the core inflation process is very much the same as the one reported by Blix (1995). Deviations of CPI inflation are substantial. Periods of under- and overestimation can be distinguished easily.

<sup>20</sup> We consider the GDP measure to be the more general proxy.

A positive demand shock shifts the AD curve to the right. In the absence of price rigidities, we would observe immediate price increases. In any case, prices adjust until the new equilibrium is reached. The adjustment process of prices gives us the shape of the impulse response function of CPI to a one ppt. increase in aggregate demand. Immediately after the demand shock an increase in the price level can be observed. After that inflation rates decrease step-by-step until the inflationary impact of the shock disappears and the new equilibrium price level is set.

In view of the theory, we find the shape of the estimated impulse response functions very convincing. The short- and long-run impacts, of course, differ across countries due to structural differences. A demand disturbance increases prices permanently, although the initial effect is much larger than the long run effect. Core shocks also increase output initially, but the effect dies out and the impulse response is close to zero, reflecting the imposed output-neutrality assumption.

The variance decomposition results are reported in Figures 11, 15, 19, 23, 27, 31, 35, 39 and 43. According to the definition of core inflation, its fluctuations are explained by core (demand) shocks. As can be seen from the variance decompositions, CPI inflation itself is to a large extent driven by core innovations. This is consistent with the results given above that core inflation tracks CPI inflation very well in most countries. With regard to the variance decompositions, this observation is most accentuated for Italy (Figure 31) and the Netherlands (Figure 35). It is less pronounced for Austria (Figure 11), Germany (Figure 27), Belgium (Figure 15), France (Figure 23) and Sweden (Figure 39). Finland (Figure 19) and the UK (Figure 43) constitute exceptions, because core and non-core innovations explain more or less equal parts of the CPI inflation forecast variance.

### 4.3 Trivariate SVAR

In a second step we differentiate monetary or LM shocks from real demand shocks. Both of these shocks were restricted not to have long-lasting effects on the level of output. This implies that both are core innovations, driving the underlying inflation process. The objective of the model extension is to investigate whether real aggregate demand and monetary innovations have similar effects on measured inflation. We also expect that the estimates for the inflation measures could be improved by the extension. We estimate a trivariate VAR system in GDP growth  $\Delta y_t$ , the change in nominal interest rates  $\Delta i_t$ , and in quarterly CPI inflation rates  $\Delta p_t$ . The estimation results for all countries are summarised in Figures 1 to 9. All growth rates (differences) are calculated on a year-on-year basis. Again, the estimation period is 1970:1 to 1996:12. The values for 1997 and 1998 are forecasts. The system includes 3 lags, which is supported by various information criteria applied.<sup>21</sup> As previously indicated, this specification is consistent with  $y_t$ ,  $i_t$  and  $p_t$  being integrated of order one. Cointegration tests do not give evidence of cointegrating vectors.<sup>22</sup>

#### 4.3.1 Core Inflation versus CPI Inflation

The estimation results for all countries are summarised again in Figures 1 to 9. Even though the core-CPI differentials differ somewhat from those obtained in the bivariate approach, the pattern of deviations closely matches the one from the previous results. In almost every case, the cyclical pattern of over- and underestimations is remarkably similar across both specifications.

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<sup>21</sup> See footnote 17, p.14.

<sup>22</sup> See footnote 16, p. 14.



For Austria, Belgium and Germany, the difference between the bivariate and the trivariate approach is negligible. For Finland, the Netherlands, Sweden and UK the deviations are minor. For France and Italy differences in the results are more important.

### 4.3.2 Impulse Response Functions and Variance Decompositions

The impulse response estimates for the trivariate VAR systems displayed in Figures 12, 16, 20, 24, 28, 32, 36, 40 and 44 reveal significant differences in the effects of real and monetary demand shocks on measured inflation. According to the theoretical background outlined above,<sup>23</sup> we expect the monetary policy or LM innovations to have negligible output and price effects for countries credibly pegging their exchange rate, and positive effects for countries with lesser credibility of the peg. Such "credibility effects" can only be found for Austria (Figure 12), Germany (Figure 28) and the Netherlands (Figure 36). As we observe negative price effects in the latter case, we might interpret this interest rate increase in the traditional manner as resulting from autonomous restrictive monetary measures. In all other countries monetary innovations increase output temporarily and prices even in the long-run.<sup>24</sup>

As in the bivariate case, we estimated variance decompositions for each country. The results are shown in Figure 13 (Austria), 17 (Belgium), 21 (Finland), 25 (France), 29 (Germany), 33 (Italy), 37 (Netherlands), 41 (Sweden) and 45 (UK). We can not fully confirm the findings by Dewachter/Lustig (1997). We have already touched upon the problem of differences in results when describing the impulse response functions for the trivariate case: Interpreting their variance decompositions, Dewachter/Lustig (1997) discovered that the inflationary process is mainly driven by monetary shocks, rather than real (core) shocks. In the long run, 75% to 95% of the variability in measured inflation are accounted for by monetary innovations. Referring to the respective figures, they conclude that inflation is really a monetary phenomenon. According to our estimates, we can share their opinion on inflation being essentially demand driven, but we cannot support the judgement of inflation being a purely monetary phenomenon.

## 5 Does Monetary Policy Co-ordination Enhance Inflation Convergence? A Correlation Analysis

In Section 4 we calculated indicators for the underlying inflation process. These core inflation indicators are considered to be more relevant assessing the sustainability of a country's inflation performance than the conventional CPI inflation measure. For the assessment of the ECB's single monetary policy, it is important to know whether there are common trends or common cycles in inflation performance of EU member states. We address this issue by analysing cross-country correlations of CPI inflation and core inflation indicators as shown in Table 2 in the appendix. In Table 1 we formulate and test hypotheses based upon such calculations, where we define "core countries" as the ones that have (at least during most of the estimation period) been tying their currency explicitly to the DEM, and Germany itself.

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<sup>23</sup> See also footnote 11, p. 12.

<sup>24</sup> Due to our identifying restrictions, we do not allow for long-run output effects of a nominal interest rate shock.

**Table 1: Hypotheses tests of cross-country correlations**

Hypothesis 1: Cross-country correlations between inflation indicators are higher if the country belongs to the "core group" (Austria, Belgium, France, Germany and the Netherlands; cases 1) rather than to the "periphery group" (Finland, Italy, Sweden, UK; cases 2).

Actual Inflation (core – periphery), 1979.4-1996.4:	$\chi^2 (69) = 343.55^{***}$
Core Inflation (2) (core – periphery), 1979.4-1996.4:	$\chi^2 (69) = 339.92^{***}$
Core Inflation (3) (core – periphery), 1979.4-1996.4:	$\chi^2 (69) = 365.33^{***}$

Hypothesis 2: Cross-country correlations between CPI inflation measures (case 2) are lower than between the core inflation measures (case 1).

Core Inflation (2) – actual Inflation, 1979.4-1996.4:	$\chi^2 (69) = 152.56^{***}$
Core Inflation (3) – actual Inflation, 1979.4-1996.4:	$\chi^2 (69) = 101.24^{***}$

Hypothesis 3: Cross-country correlations of inflation measures are higher in the 1990ies (cases 1) than before (cases 2).

Actual Inflation (1987.4-1996.4 – 1979.4-1988.4):	$\chi^2 (37) = 343.55^{***}$
Core Inflation (2) (1987.4-1996.4 – 1979.4-1988.4):	$\chi^2 (37) = 339.92$
Core Inflation (3) (1987.4-1996.4 – 1979.4-1988.4):	$\chi^2 (37) = 365.33$

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\*\*\* denotes significance at the 1% level. The numbers in parentheses attached to core inflation indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively. The chi-square test statistic is calculated including a multiplier correction equal to the number of countries as follows:  $\chi^2$  (degrees of freedom) = (number of observations – number of countries)  $\times$  (log determinant(case 1) – log determinant(case 2)), where log determinants are calculated from the variance-covariance matrix of the cross-country correlations of the respective series.

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As can be seen, the correlations between inflation indicators across the countries analysed are significantly higher if the country belongs to the "core group" (Austria, Belgium, France, Germany and the Netherlands) rather than to the "periphery group" (Finland, Italy, Sweden, UK) as one would expect. Furthermore, as expected, cross-country correlations between CPI inflation measures are significantly lower than the ones between core inflation measures.

Testing the third hypothesis we find cross-country correlations for actual inflation to be significantly higher in the 1990ies than before, an outcome we would expect due to enhanced monetary policy co-ordination and economic integration in the last years. Interestingly this does not hold for core inflation measures, pointing to the close relationship of this demand-driven component of inflation across countries over the whole period.

Further analysis to measure common inflation trends in the EU then could include cointegration analysis of actual and core inflation series.

## 6 Conclusions

We calculated core inflation indicators for Austria, Belgium, Finland, France, Germany, Italy, the Netherlands, Sweden and the United Kingdom in a structural VAR framework applying long-run identification schemes similar to the ones proposed by Quah/Vahey (1995). As also suggested by their work we included a third variable in the VAR system, short-term nominal interest rates, which we assumed to capture the effects of monetary disturbances in the system.

Contrasting the results (when applicable) to those of Blix (1995) and De-wachter/Lustig (1997), they differ in many respects for obvious reasons: First of all, we

used quarterly instead of monthly data, because we included GDP instead of industrial production data in our analysis. Secondly, especially in the trivariate case, we used a different identification scheme (e.g., both Blix, 1995, and Dewachter/Lustig, 1997, included cointegrating restrictions motivated by economic theory). Specifically, we use changes of prices instead of changes in inflation in our estimations and impose respective long-term restrictions in this context.

The analysis is based on an IS-LM/AS-AD framework for small open economies and/or countries with fixed exchange rate regimes. Dewachter/Lustig (1997) find that the inflation process is mainly driven by monetary shocks, rather than demand shocks. Hence, they conclude that inflation is a monetary phenomenon. According to our estimates, we find that inflation is essentially demand-driven, but our results at this stage do not support their view that inflation is a purely monetary phenomenon.

A cross correlation analysis completes the paper, this exercise being a first attempt to address the question about the existence of common inflation trends in EU countries. Future research should aim for an in-depth analysis of common trends and cycles among EU inflation measures.

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## 8 Appendix A: Confidence Bands of Impulse Response Functions

In order to report two-standard error bands in the graphs of the impulse response functions as shown below we apply a Monte-Carlo approach. Although there is a common procedure for the "traditional" VARs that use short-term restrictions to identify the structural shocks, the calculation of the error bands for VARs using long-run restrictions are, as of now, not common knowledge among model builders. So far, also an analytical approach - which is given by Lütkepohl (1993, p.313ff) for "traditional" VARs - has not been finally designed in the context of long-run identifying restrictions.<sup>25</sup> Here we use a slightly modified version of a technique expounded in, e.g., Mélitz/Weber (1996).<sup>26</sup>

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<sup>25</sup> But see the suggestion by Vlaar (1998).

<sup>26</sup> For the calculations we modify a RATS program procedure given in Doan (1992, p.10-5).

If we write the VAR as

$$y_t = (\mathbf{I} \otimes x_t) \boldsymbol{\beta} + u_t$$

where  $\otimes$  is the Kronecker product,  $x_t$  is the vector of lagged  $y_{it}$ 's ( $i=1,2,\dots,m$ ),  $\boldsymbol{\beta}$  is a vector containing the stacked version of the structural VAR lag polynomial matrices,  $A(L)$ , and  $u_t$  is i.i.d. with distribution  $N(0, \boldsymbol{\Sigma})$ . The OLS estimates of  $\boldsymbol{\beta}$  and  $\boldsymbol{\Sigma}$  are denoted by  $b$  and  $Z$ . Assuming that the prior distribution of  $\boldsymbol{\beta}$  is  $f(\boldsymbol{\beta}, \boldsymbol{\Sigma}) \propto |\boldsymbol{\Sigma}|^{-(n+1)/2}$ , the posterior distribution of  $\boldsymbol{\beta}$ , conditional on  $\boldsymbol{\Sigma}$ , is  $N(b, \boldsymbol{\Sigma} \otimes (x'x)^{-1})$  and the distribution of  $\boldsymbol{\Sigma}^{-1}$  is  $\text{Wishart}((TZ)^{-1}, T)$  with  $T$  as sample size.

First and second moments for the impulse responses (the moving average representation) can be computed by drawing  $q$  times<sup>27</sup> from the above distribution for  $\boldsymbol{\beta}$  and  $\boldsymbol{\Sigma}$ , inverting the VAR, calculating each time<sup>28</sup> the innovation-orthogonalising matrix  $\mathbf{E}_0^{-1}$  (as shown in the text) and conditional on that calculating the mean and the variance impulse responses (moving average parameters).

In order to derive standard errors for the accumulated impulse responses as shown in the graphs (for "level series"), we accumulate the impulses of each of the  $q$  draws for every impulse step period  $p$ , calculate their variance over the  $q$  draws and then adjust this variance in each impulse step, multiplying it by  $p^{-1}$ . The standard errors are then given by the square root of the resulting adjusted variances. We perform this adjustment referring to the fact that the identifying restrictions are imposed on the long-run moving average parameters, i.e. the accumulations of the moving average parameters derived from the estimated model with differenced series, and any variance of the accumulated parameters at step  $p$  has to be treated as sample variance of the parameters up to step  $p$ .

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<sup>27</sup> We used  $q = 300$  for our calculations.

<sup>28</sup> Here we differ from the approach as given in Melitz/Weber (1996); they perform the calculations conditional on  $\mathbf{E}_0^{-1}$  as derived from the initial estimation.

## 9 Appendix B: Tables and Graphs

**Table 2: Cross Correlations of Inflation Series between Countries**

		Belgium	Finland	France	Germany	Italy	Netherlands	Sweden	U. Kingdom
Austria	Actual Infl.	0,88	0,83	0,76	0,82	0,72	0,94	0,57	0,73
	1971:1-96:4								
	Core Infl. (2)	0,92	0,82	0,72	0,84	0,73	0,96	0,61	0,68
	Core Infl. (3)	0,81	0,74	0,76	0,82	0,85	0,92	0,71	0,36
	Actual-Core (2)	0,56	0,32	0,59	0,42	0,12	0,57	0,04	0,50
	Actual-Core (3)	0,14	0,11	0,58	0,40	0,07	0,36	0,34	0,29
1971:1-80:4	Actual Infl.	0,85	0,73	0,35	0,73	0,33	0,92	0,10	0,44
	Core Infl. (2)	0,85	0,65	0,14	0,81	0,36	0,92	-0,08	0,32
	Core Infl. (3)	0,59	0,66	0,87	-0,12	0,94	0,93	0,51	-0,24
	Actual-Core (2)	0,64	0,33	0,74	0,60	0,35	0,69	-0,07	0,67
	Actual-Core (3)	-0,51	0,95	0,67	-0,01	-0,88	0,84	0,97	0,39
1981:1-90:4	Actual Infl.	0,82	0,81	0,86	0,84	0,83	0,93	0,74	0,62
	Core Infl. (2)	0,86	0,88	0,84	0,90	0,86	0,96	0,92	0,07
	Core Infl. (3)	0,85	0,85	0,81	0,89	0,86	0,95	0,83	0,00
	Actual-Core (2)	0,49	0,27	0,70	0,35	-0,14	0,49	-0,25	0,37
	Actual-Core (3)	0,24	0,23	0,76	0,34	-0,19	0,34	-0,04	0,20
1990:1-96:4	Actual Infl.	0,65	0,57	0,37	0,80	0,36	0,65	0,42	0,22
	Core Infl. (2)	0,69	0,06	0,61	0,86	0,39	0,73	0,54	-0,02
	Core Infl. (3)	0,64	0,56	0,64	0,84	0,24	0,69	0,44	0,11
	Actual-Core (2)	0,45	0,43	0,45	0,46	0,21	0,71	0,53	0,23
	Actual-Core (3)	0,07	-0,16	0,46	0,52	0,22	0,31	0,69	0,29
Belgium	Actual Infl.	1,00	0,89	0,84	0,68	0,82	0,85	0,63	0,75
	1971:1-96:4								
	Core Infl. (2)	1,00	0,90	0,82	0,72	0,79	0,89	0,67	0,79
	Core Infl. (3)	1,00	0,84	0,88	0,75	0,83	0,76	0,74	0,43
	Actual-Core (2)	1,00	0,10	0,67	0,30	-0,11	0,34	0,01	0,31
	Actual-Core (3)	1,00	-0,68	0,41	0,08	-0,25	-0,36	-0,31	-0,09
1971:1-80:4	Actual Infl.	1,00	0,89	0,56	0,48	0,51	0,82	0,24	0,64
	Core Infl. (2)	1,00	0,90	0,38	0,52	0,57	0,85	0,09	0,56
	Core Infl. (3)	1,00	0,89	0,48	0,27	0,82	0,74	0,67	-0,61
	Actual-Core (2)	1,00	0,50	0,84	0,60	0,39	0,51	0,07	0,80
	Actual-Core (3)	1,00	-0,61	-0,96	0,39	0,61	-0,49	-0,37	0,43
1981:1-90:4	Actual Infl.	1,00	0,81	0,90	0,83	0,92	0,85	0,66	0,41
	Core Infl. (2)	1,00	0,92	0,83	0,89	0,83	0,84	0,80	-0,08
	Core Infl. (3)	1,00	0,89	0,89	0,90	0,88	0,87	0,78	0,02
	Actual-Core (2)	1,00	-0,07	0,71	0,17	-0,28	0,42	-0,18	0,38
	Actual-Core (3)	1,00	-0,71	0,43	-0,02	-0,40	-0,28	-0,35	0,12
1990:1-96:4	Actual Infl.	1,00	0,81	0,75	0,38	0,42	0,56	0,75	0,61
	Core Infl. (2)	1,00	0,26	0,94	0,73	0,17	0,55	0,70	0,15
	Core Infl. (3)	1,00	0,47	0,90	0,78	-0,18	0,38	0,57	0,17
	Actual-Core (2)	1,00	-0,38	0,90	0,49	-0,44	0,22	0,04	-0,62
	Actual-Core (3)	1,00	-0,85	0,79	0,31	-0,61	-0,57	-0,34	-0,83
Finland	Actual Infl.		1,00	0,86	0,63	0,84	0,82	0,77	0,88
	1971:1-96:4								
	Core Infl. (2)		1,00	0,91	0,58	0,83	0,80	0,77	0,89
	Core Infl. (3)		1,00	0,93	0,49	0,85	0,66	0,80	0,70
	Actual-Core (2)		1,00	0,23	0,31	0,05	0,31	0,44	0,60
	Actual-Core (3)		1,00	-0,22	-0,08	0,44	0,44	0,30	0,38
1971:1-80:4	Actual Infl.		1,00	0,58	0,40	0,58	0,73	0,43	0,77
	Core Infl. (2)		1,00	0,40	0,27	0,60	0,64	0,12	0,69
	Core Infl. (3)		1,00	0,36	-0,19	0,79	0,73	0,58	-0,85
	Actual-Core (2)		1,00	0,61	0,47	-0,31	0,19	0,29	0,66
	Actual-Core (3)		1,00	0,79	0,00	-0,82	0,70	0,95	0,33
1981:1-90:4	Actual Infl.		1,00	0,90	0,91	0,87	0,88	0,78	0,68
	Core Infl. (2)		1,00	0,95	0,89	0,95	0,92	0,83	0,09
	Core Infl. (3)		1,00	0,94	0,84	0,91	0,92	0,73	0,18
	Actual-Core (2)		1,00	0,38	0,62	0,61	0,50	0,55	0,21
	Actual-Core (3)		1,00	0,06	0,19	0,36	0,44	0,55	-0,01
1990:1-96:4	Actual Infl.		1,00	0,88	0,33	0,74	0,40	0,90	0,84
	Core Infl. (2)		1,00	0,44	-0,22	0,35	-0,13	0,68	0,96
	Core Infl. (3)		1,00	0,50	0,36	0,01	0,16	0,62	0,50
	Actual-Core (2)		1,00	-0,38	-0,09	0,49	0,50	0,58	0,86
	Actual-Core (3)		1,00	-0,71	-0,39	0,53	0,60	0,16	0,66

(to be continued)

**Table 2: Cross Correlations of Inflation Series between Countries (continued)**

		Belgium	Finland	France	Germany	Italy	Netherlands	Sweden	U. Kingdom
France	Actual Infl.			1,00	0,63	0,95	0,75	0,75	0,77
1971:1-96:4	Core Infl. (2)			1,00	0,57	0,88	0,69	0,86	0,77
	Core Infl. (3)			1,00	0,56	0,91	0,70	0,84	0,73
	Actual-Core (2)			1,00	0,47	-0,16	0,48	-0,04	0,45
	Actual-Core (3)			1,00	0,44	-0,38	0,42	0,05	0,24
1971:1-80:4	Actual Infl.			1,00	0,14	0,89	0,15	0,58	0,66
	Core Infl. (2)			1,00	-0,25	0,88	-0,02	0,82	0,37
	Core Infl. (3)			1,00	0,20	0,85	0,89	0,61	0,17
	Actual-Core (2)			1,00	0,67	0,38	0,58	0,03	0,81
	Actual-Core (3)			1,00	-0,34	-0,73	0,53	0,57	-0,26
1981:1-90:4	Actual Infl.			1,00	0,86	0,96	0,92	0,65	0,52
	Core Infl. (2)			1,00	0,83	0,98	0,90	0,73	0,12
	Core Infl. (3)			1,00	0,83	0,96	0,90	0,69	0,19
	Actual-Core (2)			1,00	0,35	-0,10	0,60	-0,07	0,57
	Actual-Core (3)			1,00	0,33	-0,18	0,46	0,16	0,34
1990:1-96:4	Actual Infl.			1,00	0,24	0,82	0,31	0,86	0,84
	Core Infl. (2)			1,00	0,66	0,35	0,37	0,81	0,32
	Core Infl. (3)			1,00	0,74	0,15	0,31	0,81	0,48
	Actual-Core (2)			1,00	0,71	-0,54	0,27	-0,19	-0,67
	Actual-Core (3)			1,00	0,68	-0,58	-0,28	-0,18	-0,62
Germany	Actual Infl.				1,00	0,56	0,84	0,44	0,57
1971:1-96:4	Core Infl. (2)				1,00	0,56	0,85	0,52	0,37
	Core Infl. (3)				1,00	0,61	0,84	0,53	0,09
	Actual-Core (2)				1,00	0,18	0,51	-0,01	0,34
	Actual-Core (3)				1,00	0,04	0,21	0,32	0,22
1971:1-80:4	Actual Infl.				1,00	0,02	0,67	-0,12	0,23
	Core Infl. (2)				1,00	-0,10	0,80	-0,34	-0,03
	Core Infl. (3)				1,00	0,08	-0,01	0,02	0,44
	Actual-Core (2)				1,00	0,38	0,49	-0,16	0,77
	Actual-Core (3)				1,00	0,48	0,06	0,19	0,82
1981:1-90:4	Actual Infl.				1,00	0,85	0,93	0,78	0,79
	Core Infl. (2)				1,00	0,82	0,92	0,89	0,10
	Core Infl. (3)				1,00	0,79	0,92	0,85	0,15
	Actual-Core (2)				1,00	0,42	0,62	0,18	0,11
	Actual-Core (3)				1,00	0,30	0,26	0,34	0,00
1990:1-96:4	Actual Infl.				1,00	0,21	0,74	0,16	-0,07
	Core Infl. (2)				1,00	0,27	0,69	0,45	-0,29
	Core Infl. (3)				1,00	0,11	0,69	0,48	0,02
	Actual-Core (2)				1,00	-0,47	0,42	-0,12	-0,34
	Actual-Core (3)				1,00	-0,44	-0,04	0,18	-0,08
Italy	Actual Infl.					1,00	0,70	0,76	0,77
1971:1-96:4	Core Infl. (2)					1,00	0,72	0,80	0,70
	Core Infl. (3)					1,00	0,84	0,76	0,57
	Actual-Core (2)					1,00	0,24	0,17	0,21
	Actual-Core (3)					1,00	0,07	0,43	0,27
1971:1-80:4	Actual Infl.					1,00	0,15	0,64	0,66
	Core Infl. (2)					1,00	0,25	0,74	0,66
	Core Infl. (3)					1,00	0,97	0,66	-0,36
	Actual-Core (2)					1,00	0,31	-0,30	0,24
	Actual-Core (3)					1,00	-0,73	-0,76	0,05
1981:1-90:4	Actual Infl.					1,00	0,90	0,67	0,47
	Core Infl. (2)					1,00	0,90	0,78	0,05
	Core Infl. (3)					1,00	0,91	0,73	0,09
	Actual-Core (2)					1,00	0,22	0,77	0,03
	Actual-Core (3)					1,00	0,33	0,48	0,02
1990:1-96:4	Actual Infl.					1,00	0,20	0,82	0,78
	Core Infl. (2)					1,00	0,15	0,64	0,34
	Core Infl. (3)					1,00	-0,06	0,31	0,26
	Actual-Core (2)					1,00	0,19	0,65	0,71
	Actual-Core (3)					1,00	0,46	0,58	0,66

(to be continued)

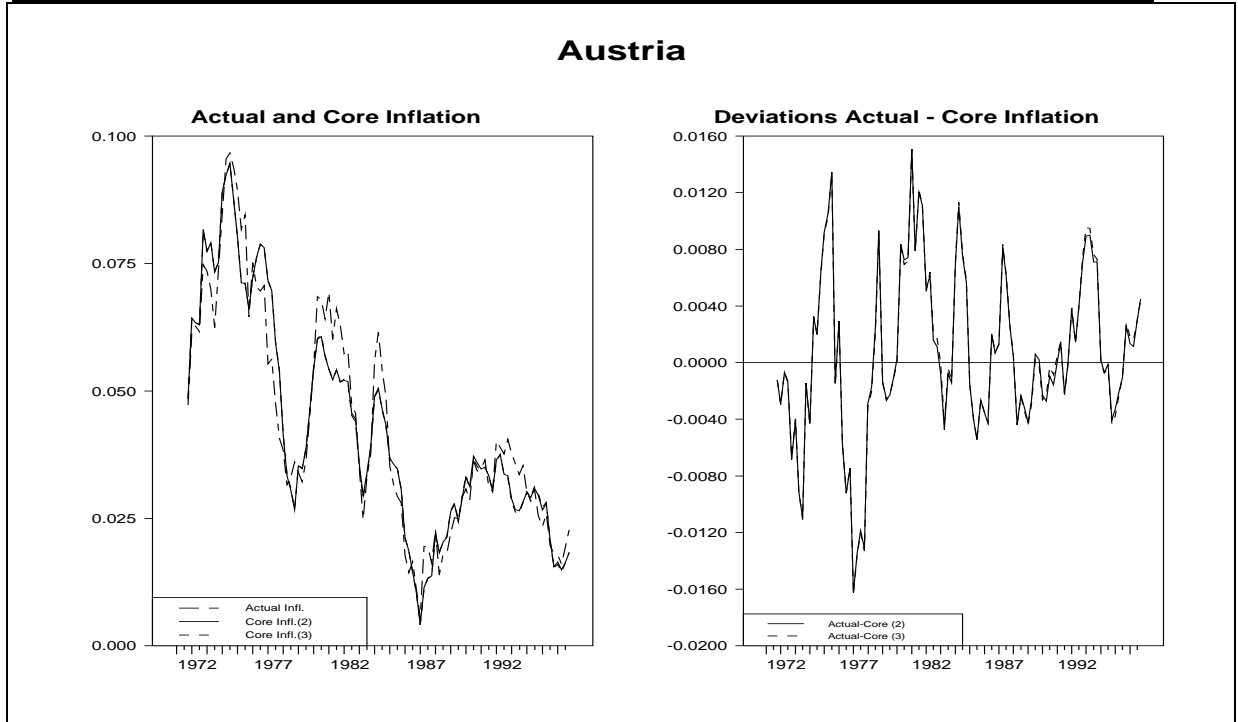


**Table 2: Cross Correlations of Inflation Series between Countries (continued)**

		Belgium	Finland	France	Germany	Italy	Netherlands	Sweden	U. Kingdom
Netherlands 1971:1-96:4	Actual Infl.						1,00	0,54	0,76
	Core Infl. (2)						1,00	0,57	0,67
	Core Infl. (3)						1,00	0,58	0,28
	Actual-Core (2)						1,00	0,23	0,46
	Actual-Core (3)						1,00	0,36	0,34
1971:1-80:4	Actual Infl.						1,00	0,02	0,44
	Core Infl. (2)						1,00	-0,18	0,32
	Core Infl. (3)						1,00	0,77	-0,28
	Actual-Core (2)						1,00	0,12	0,55
	Actual-Core (3)						1,00	0,78	0,29
1981:1-90:4	Actual Infl.						1,00	0,78	0,73
	Core Infl. (2)						1,00	0,88	0,18
	Core Infl. (3)						1,00	0,80	0,17
	Actual-Core (2)						1,00	0,22	0,28
	Actual-Core (3)						1,00	0,34	0,12
1990:1-96:4	Actual Infl.						1,00	0,26	0,12
	Core Infl. (2)						1,00	0,37	-0,08
	Core Infl. (3)						1,00	0,11	-0,11
	Actual-Core (2)						1,00	0,44	0,36
	Actual-Core (3)						1,00	0,43	0,61
Sweden 1971:1-96:4	Actual Infl.							1,00	0,71
	Core Infl. (2)							1,00	0,66
	Core Infl. (3)							1,00	0,75
	Actual-Core (2)							1,00	0,18
	Actual-Core (3)							1,00	0,42
1971:1-80:4	Actual Infl.							1,00	0,53
	Core Infl. (2)							1,00	0,27
	Core Infl. (3)							1,00	-0,27
	Actual-Core (2)							1,00	0,07
	Actual-Core (3)							1,00	0,57
1981:1-90:4	Actual Infl.							1,00	0,72
	Core Infl. (2)							1,00	0,03
	Core Infl. (3)							1,00	0,07
	Actual-Core (2)							1,00	0,25
	Actual-Core (3)							1,00	0,29
1990:1-96:4	Actual Infl.							1,00	0,83
	Core Infl. (2)							1,00	0,65
	Core Infl. (3)							1,00	0,80
	Actual-Core (2)							1,00	0,56
	Actual-Core (3)							1,00	0,71

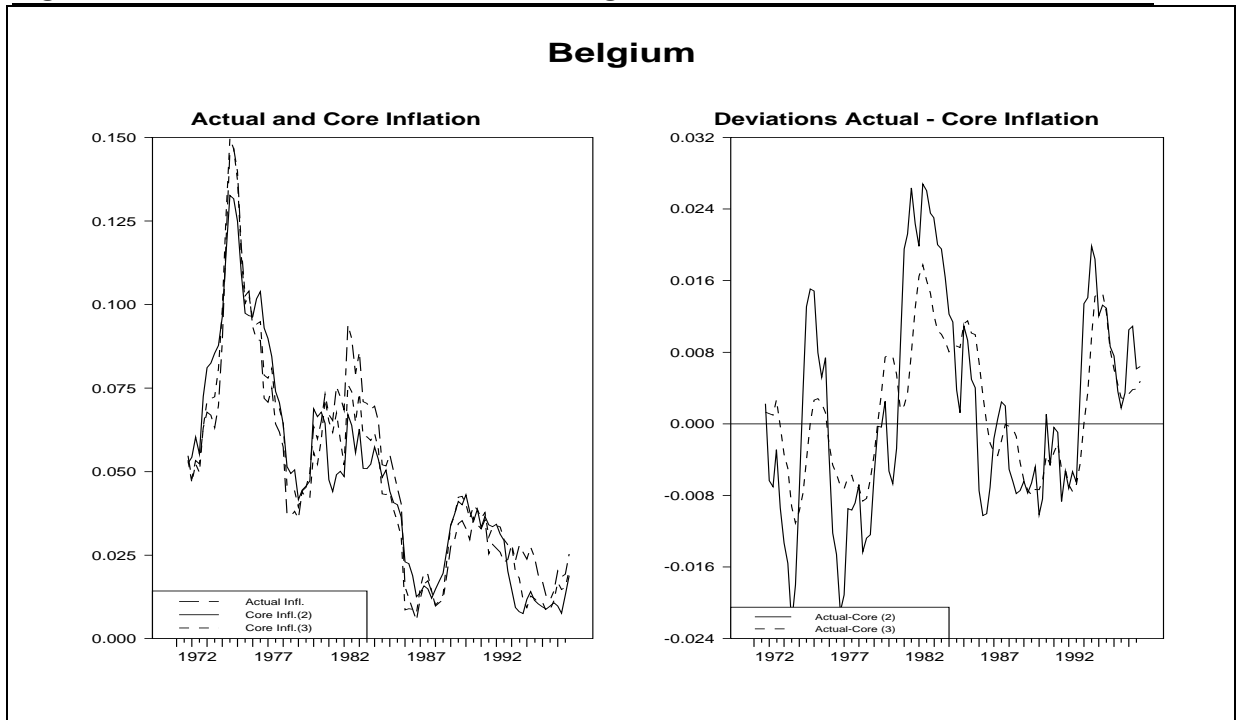
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 1: Inflation and Core Inflation in Austria



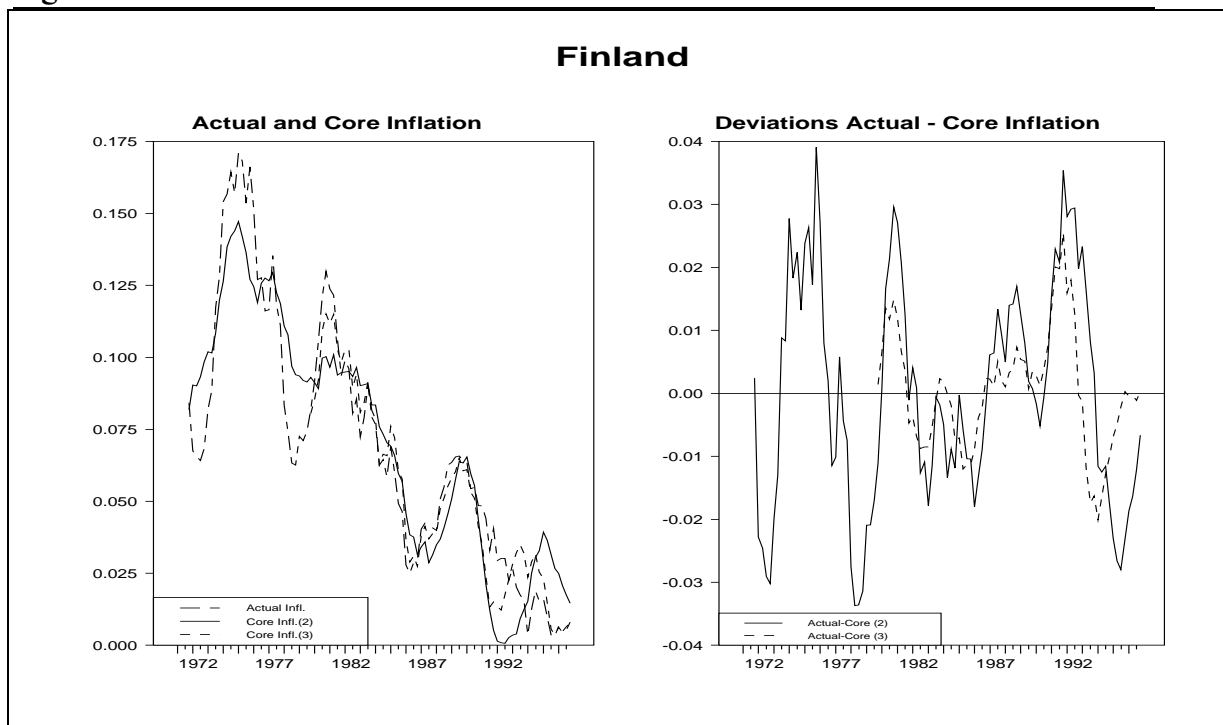
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 2: Inflation and Core Inflation in Belgium



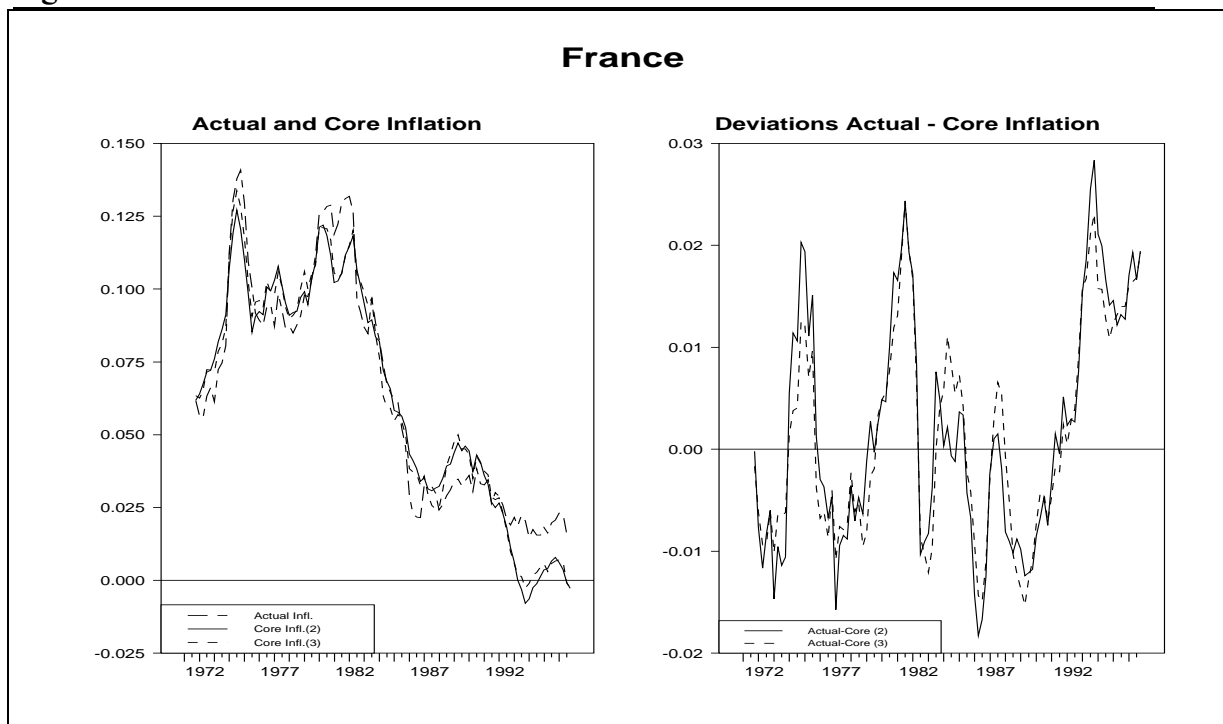
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 3: Inflation and Core Inflation in Finland



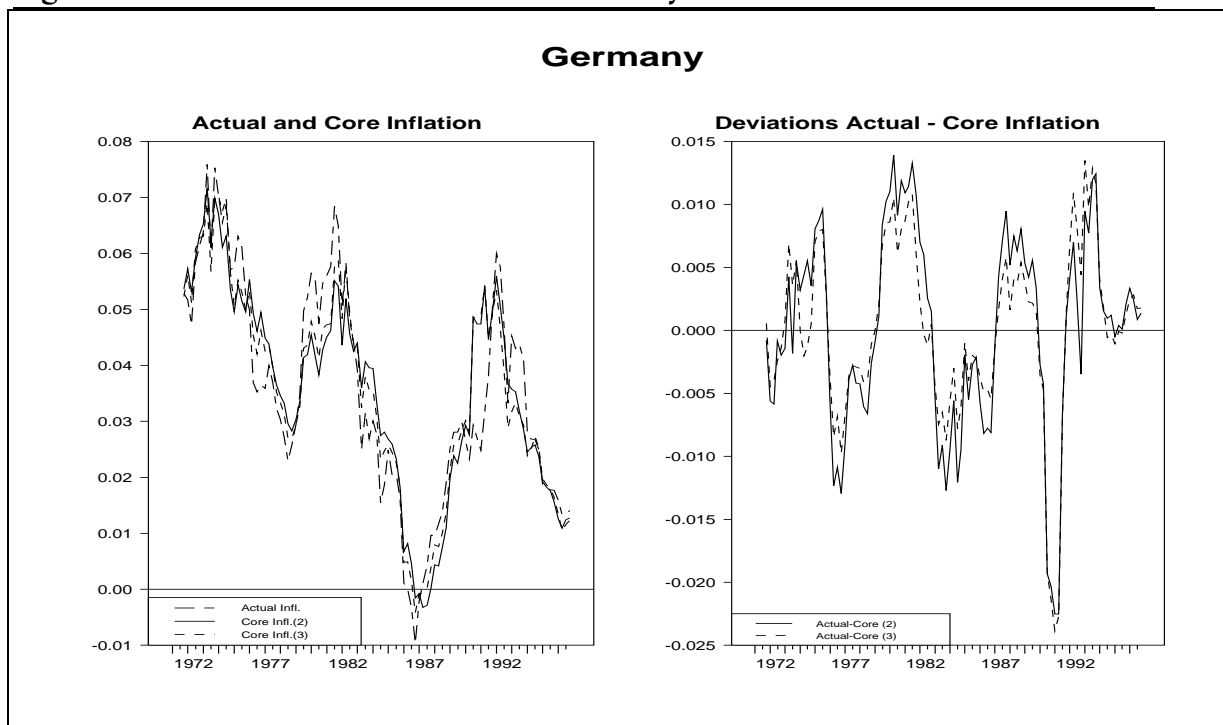
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 4: Inflation and Core Inflation in France



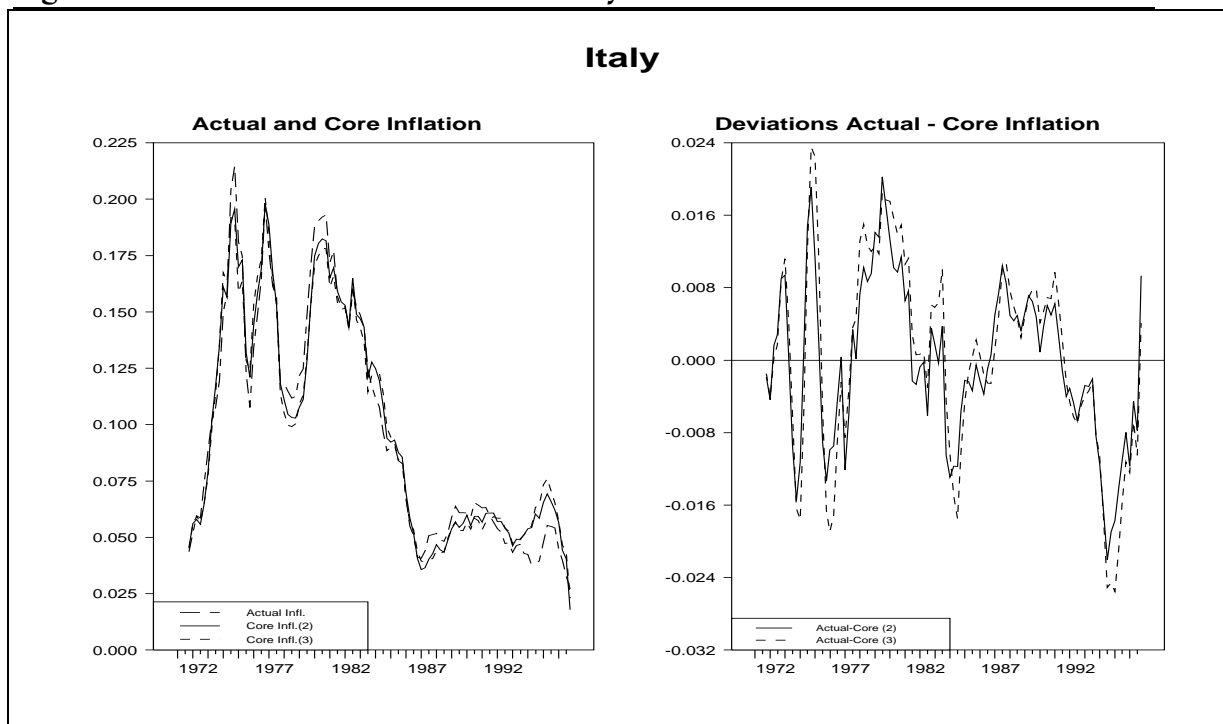
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 5: Inflation and Core Inflation in Germany



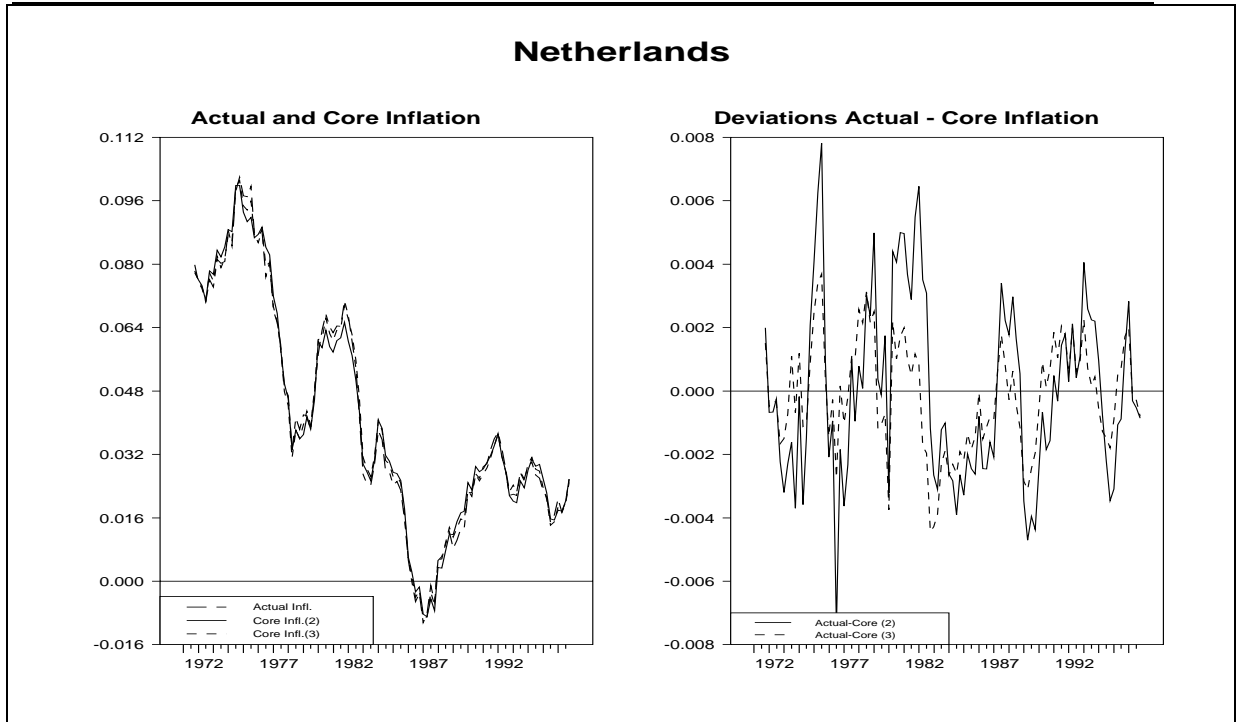
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 6: Inflation and Core Inflation in Italy



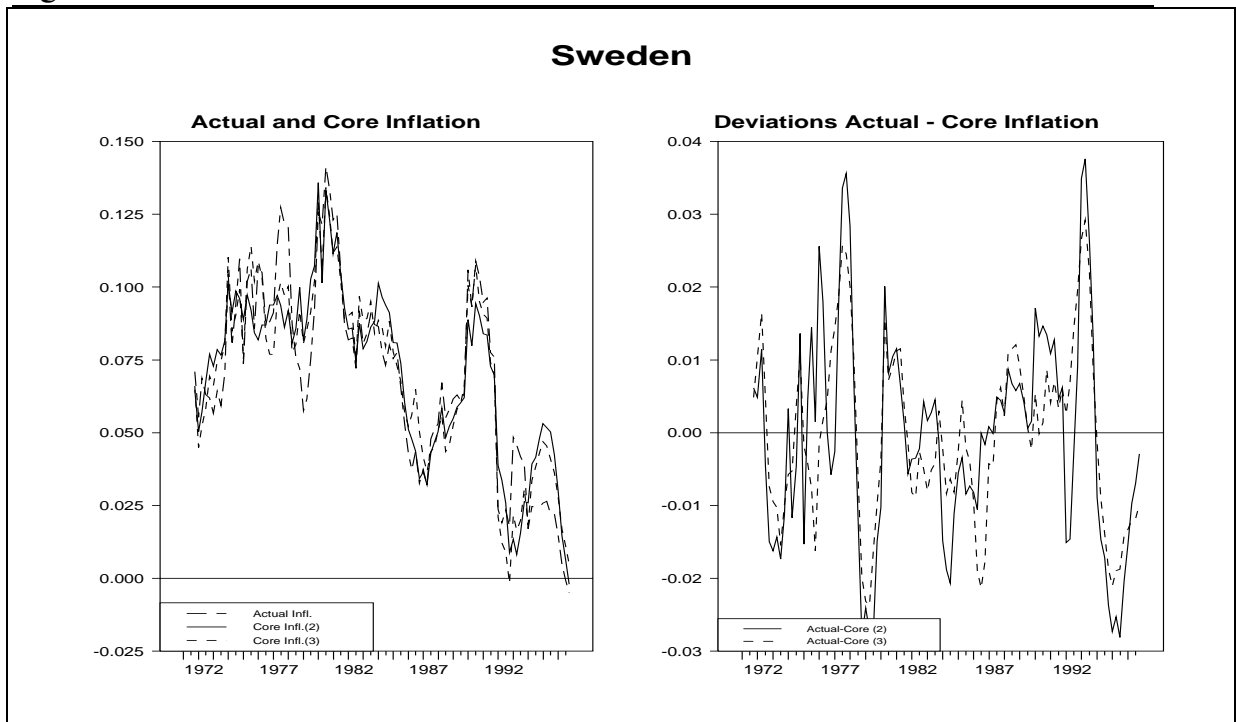
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 7: Inflation and Core Inflation in the Netherlands



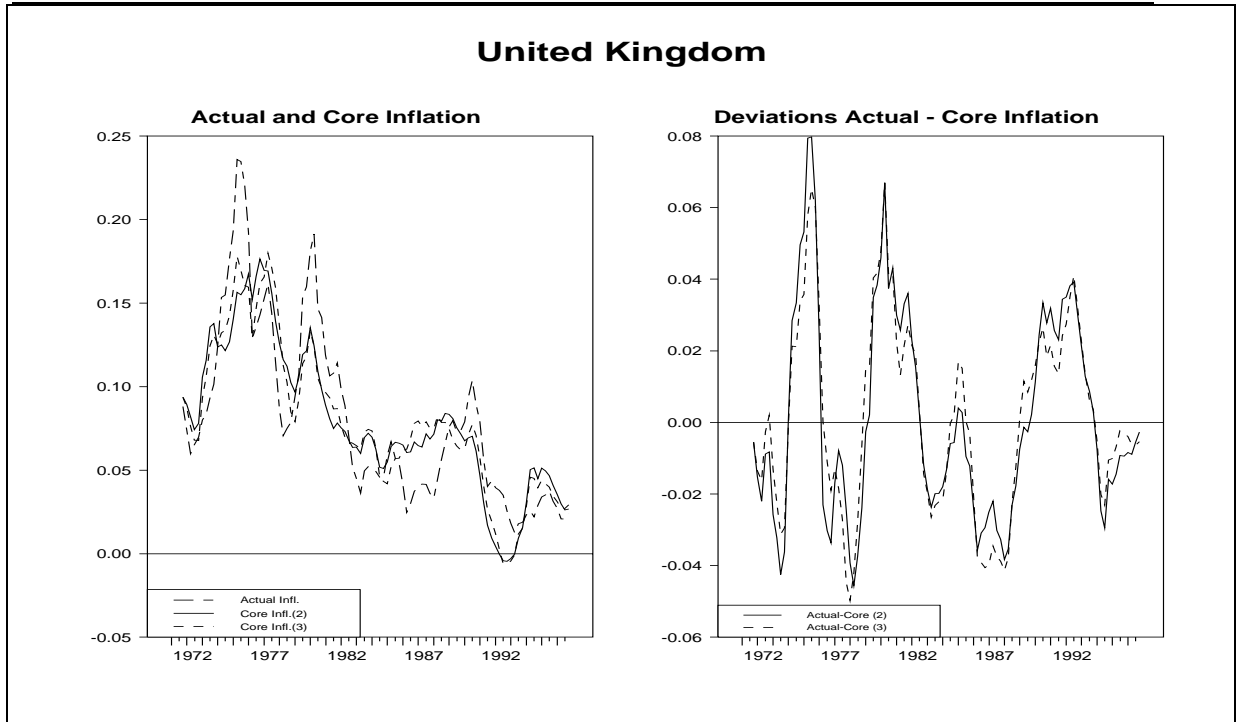
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 8: Inflation and Core Inflation in Sweden



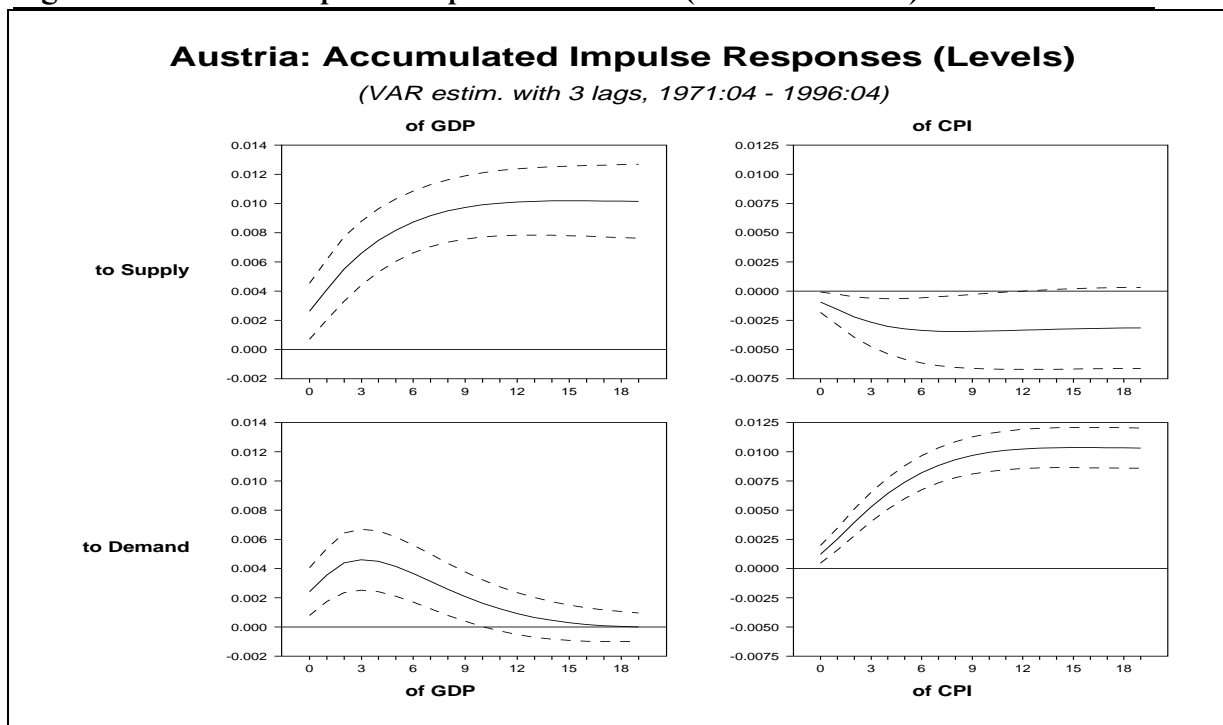
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 9: Inflation and Core Inflation in the United Kingdom



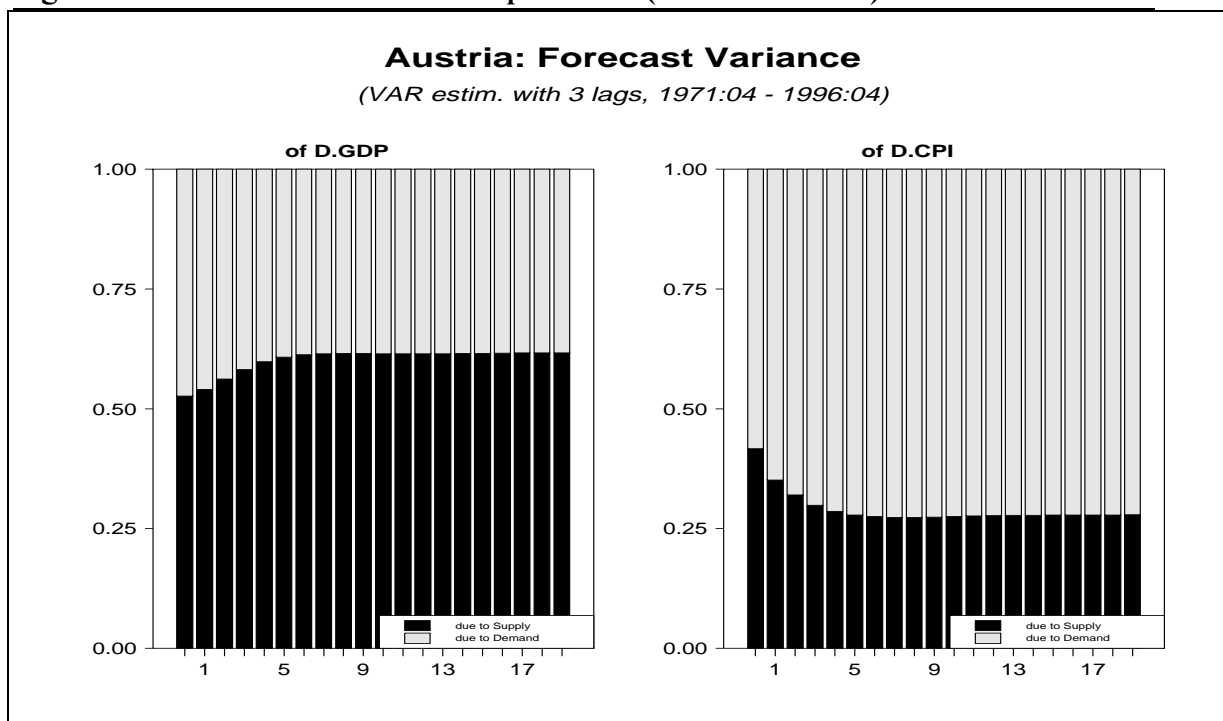
Note: The numbers in parentheses indicate the results of the bivariate (output, inflation) and trivariate (output, interest rate and inflation) model, respectively.

Figure 10: Austria - Impulse Response Functions (bivariate model)



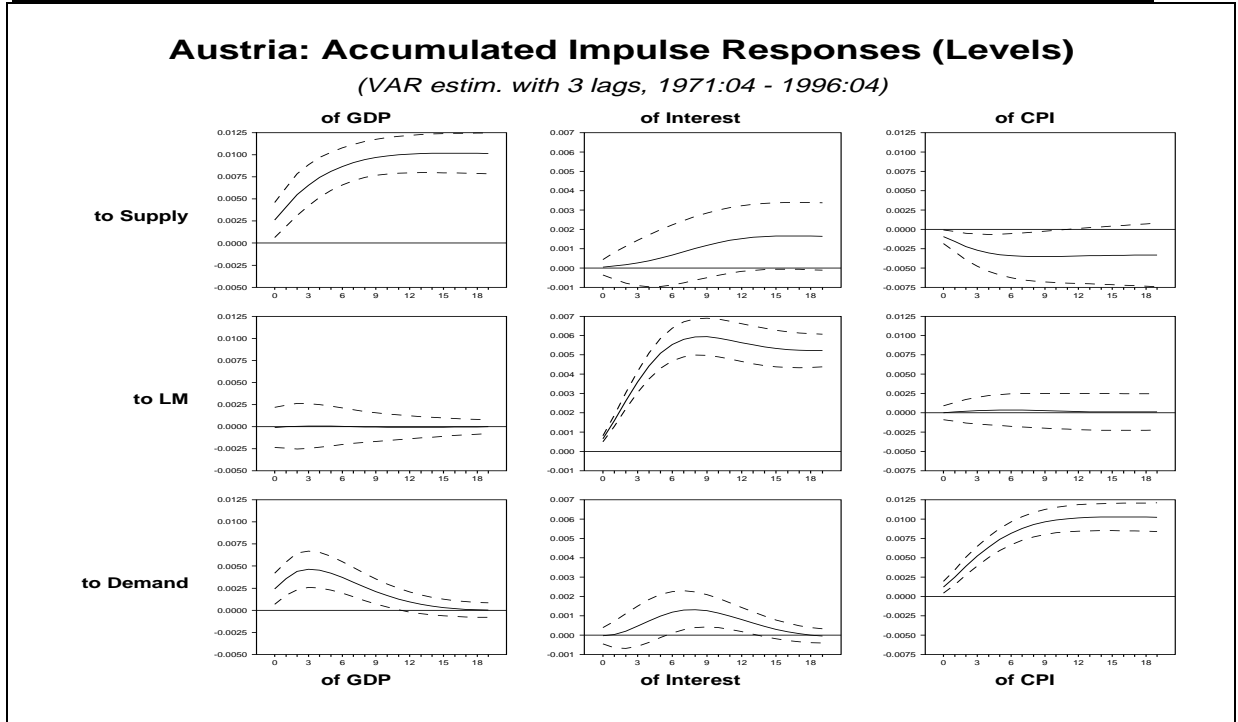
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 11: Austria - Variance Decompositions (bivariate model)



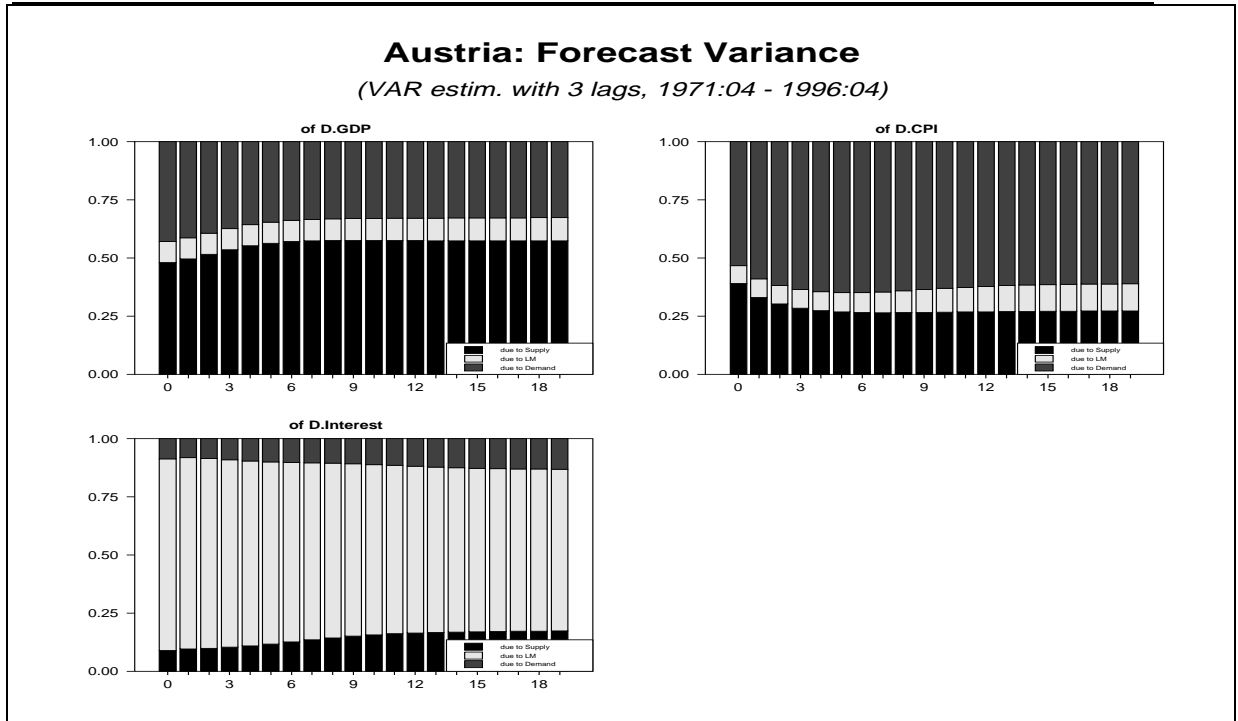
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 12: Austria - Impulse Response Functions (trivariate model)



Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

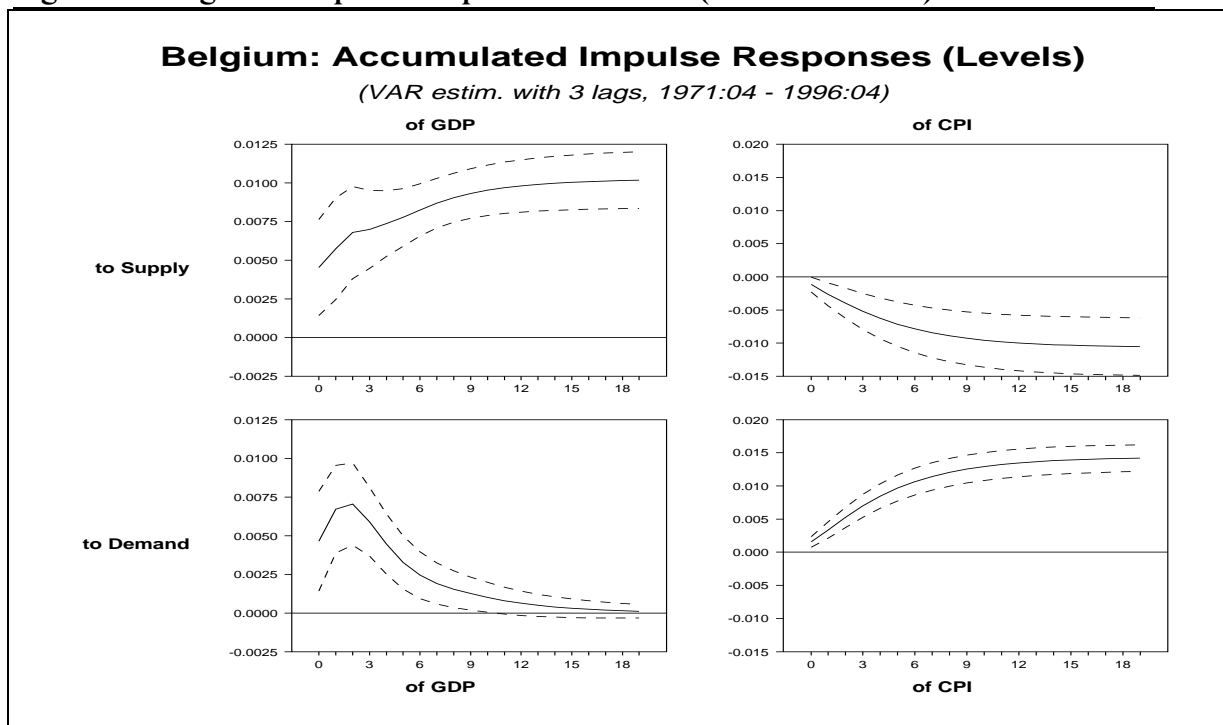
Figure 13: Austria - Variance Decompositions (trivariate model)



Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

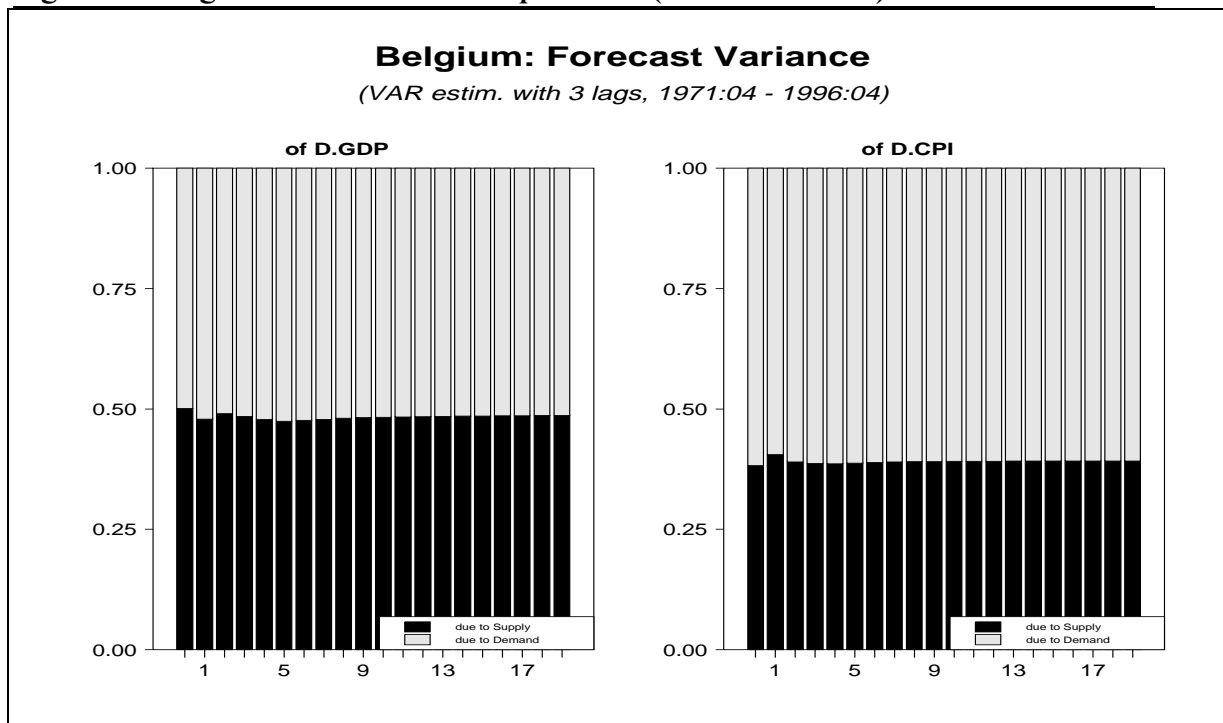


Figure 14: Belgium - Impulse Response Functions (bivariate model)



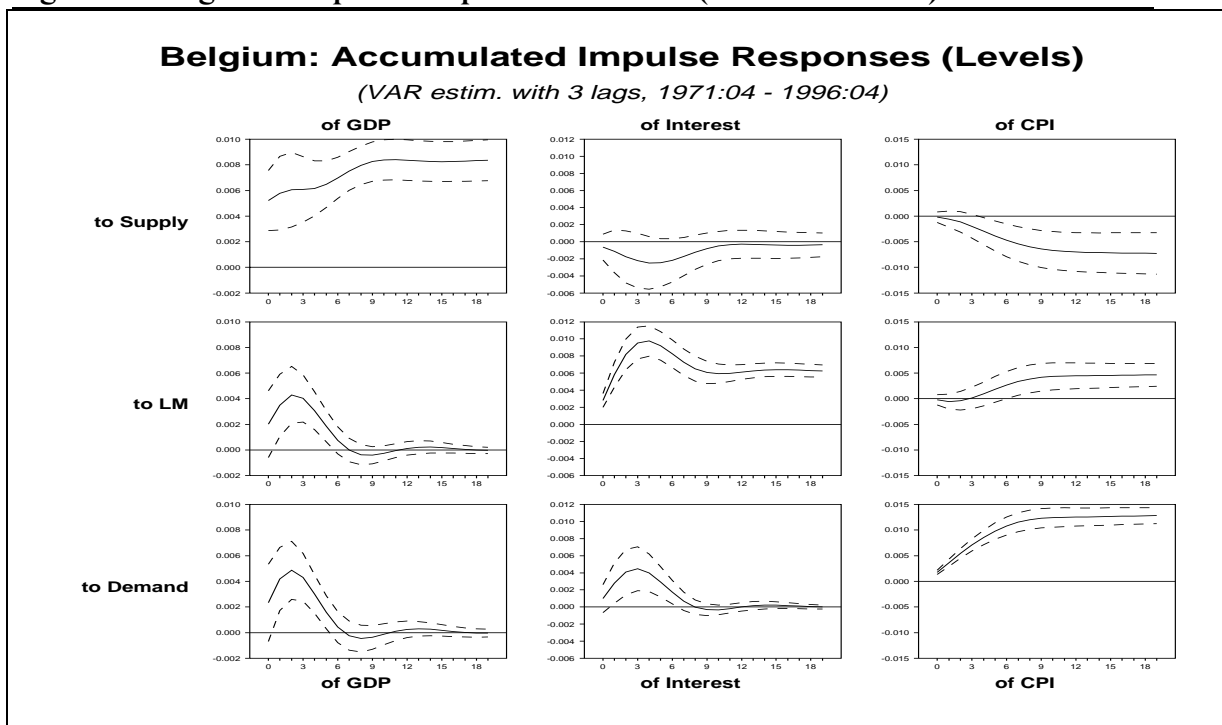
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 15: Belgium - Variance Decompositions (bivariate model)



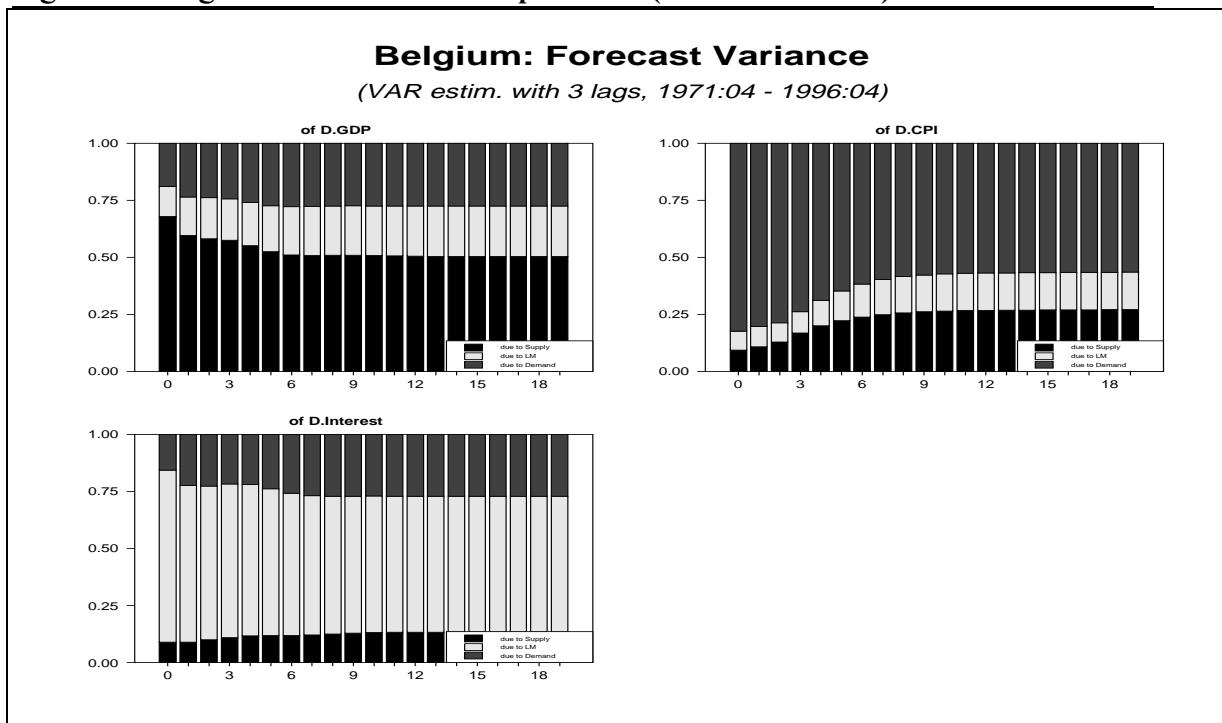
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 16: Belgium - Impulse Response Functions (trivariate model)



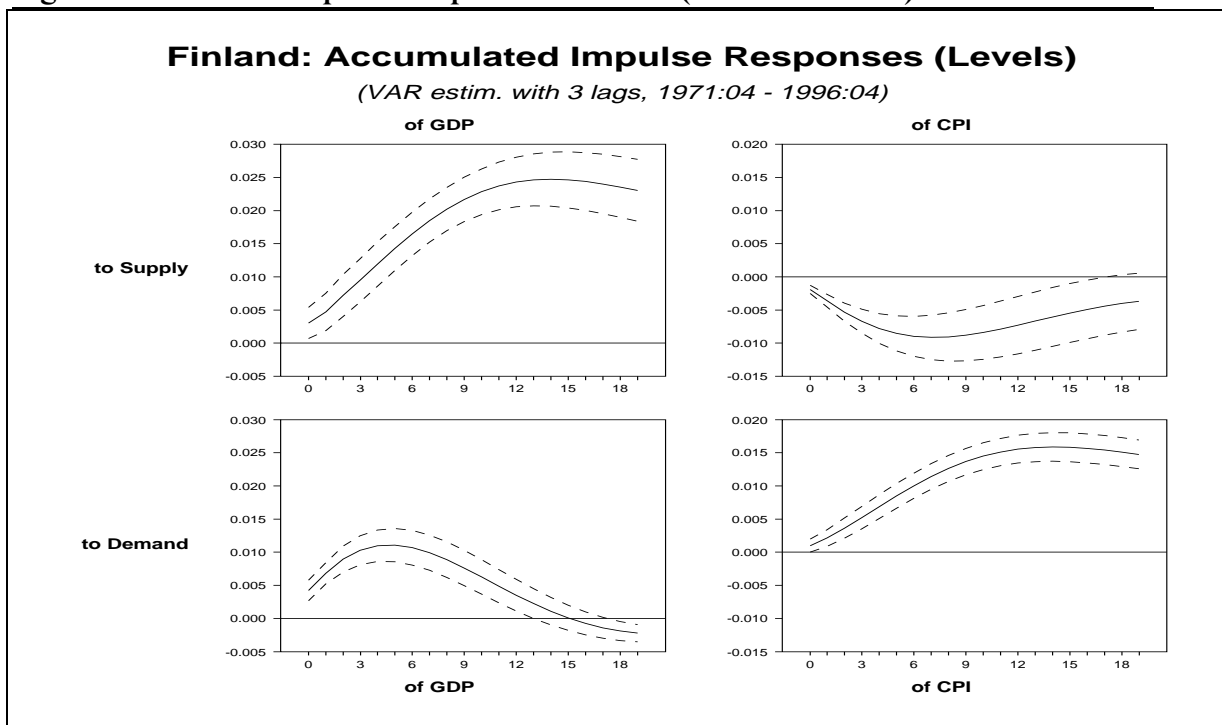
Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 17: Belgium - Variance Decompositions (trivariate model)



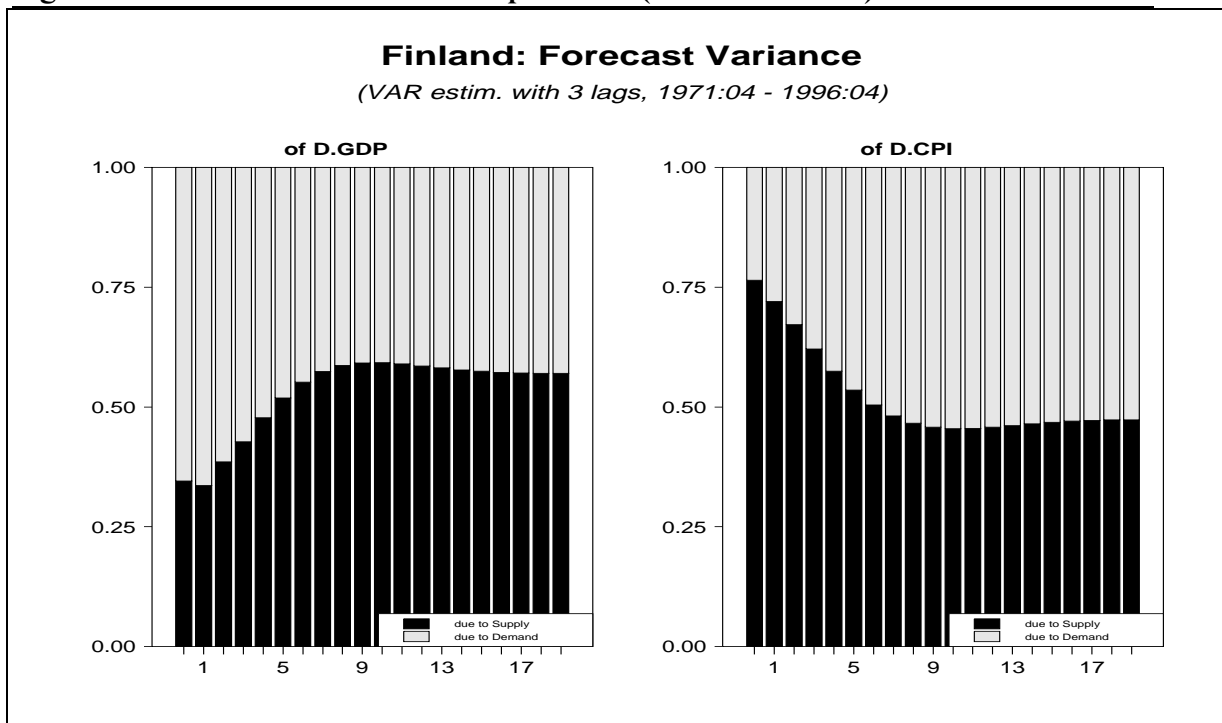
Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 18: Finland - Impulse Response Functions (bivariate model)



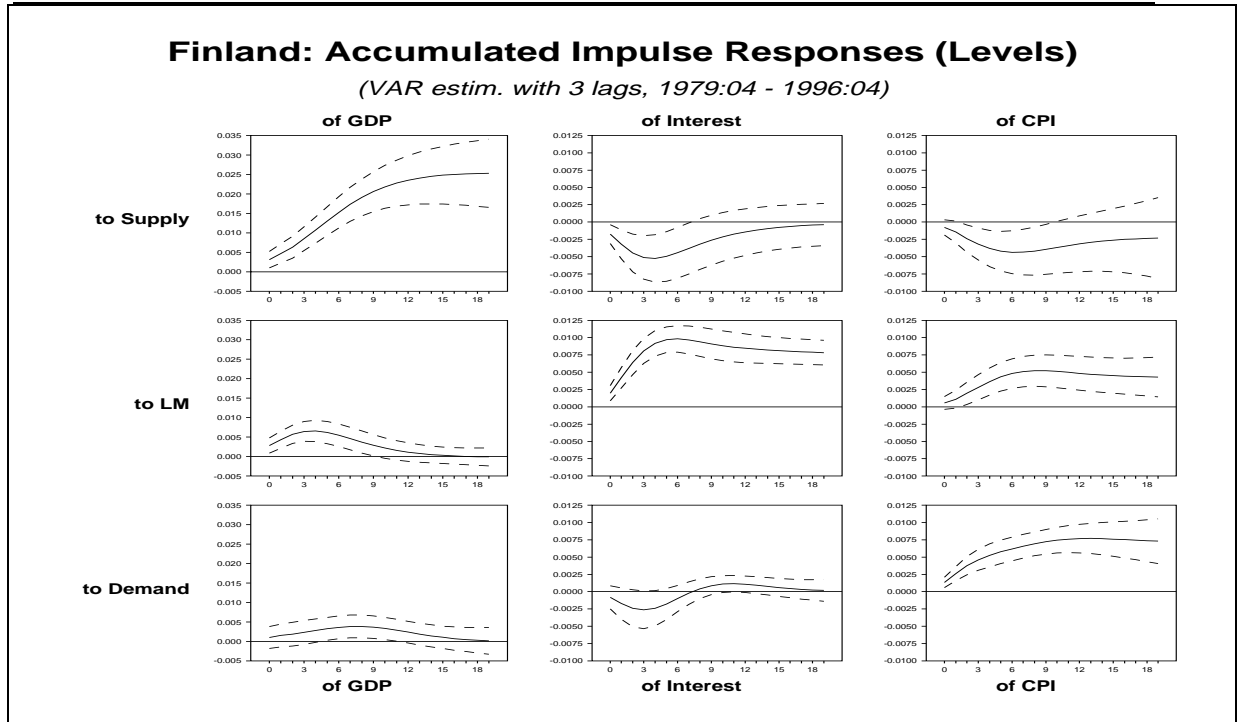
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 19: Finland - Variance Decompositions (bivariate model)



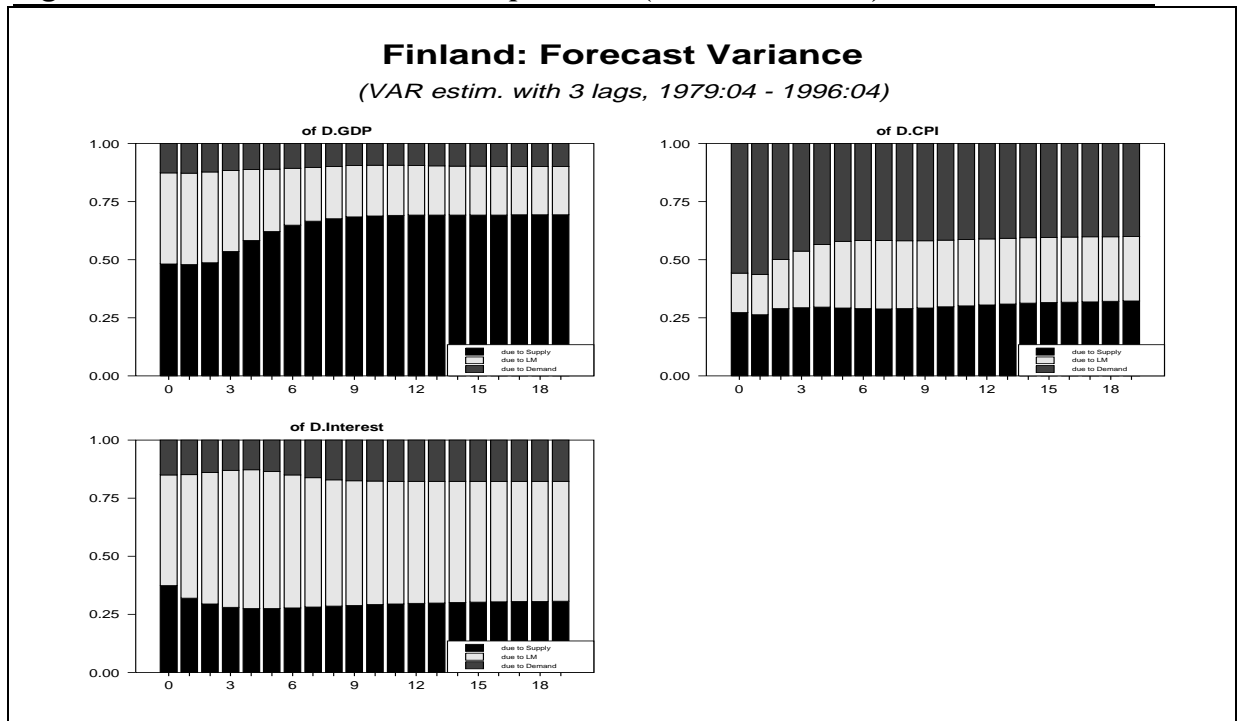
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 20: Finland - Impulse Response Functions (trivariate model)



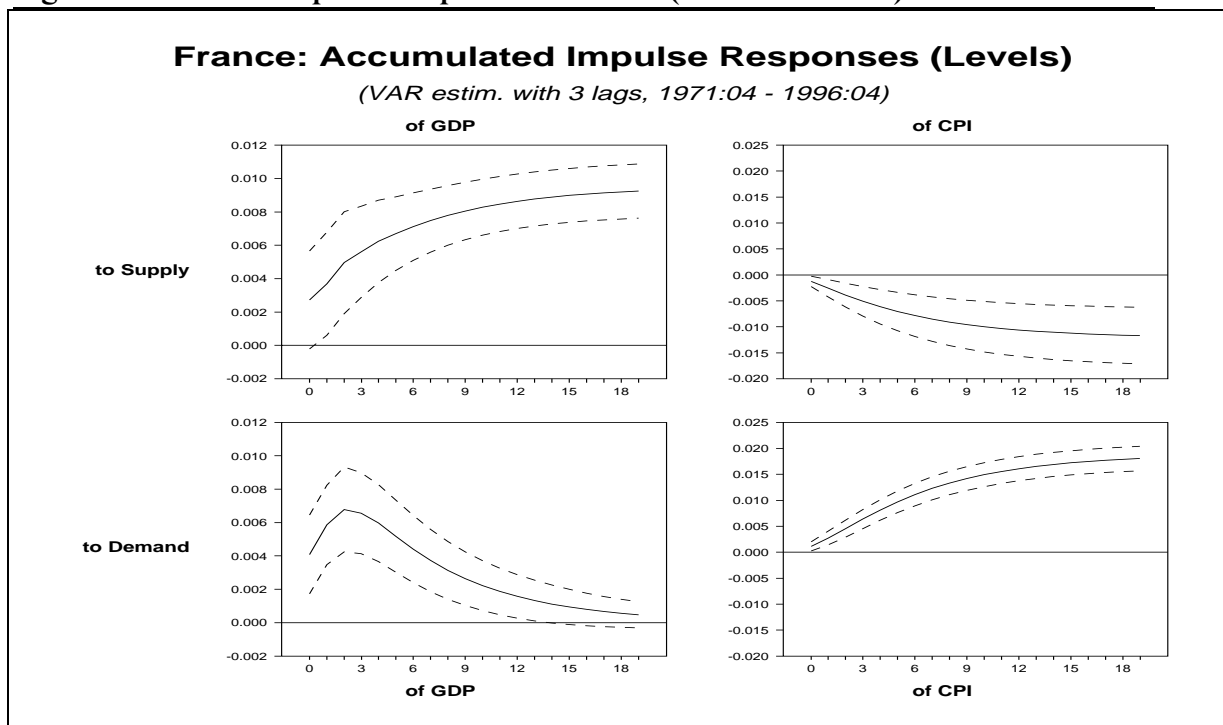
Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 21: Finland - Variance Decompositions (trivariate model)



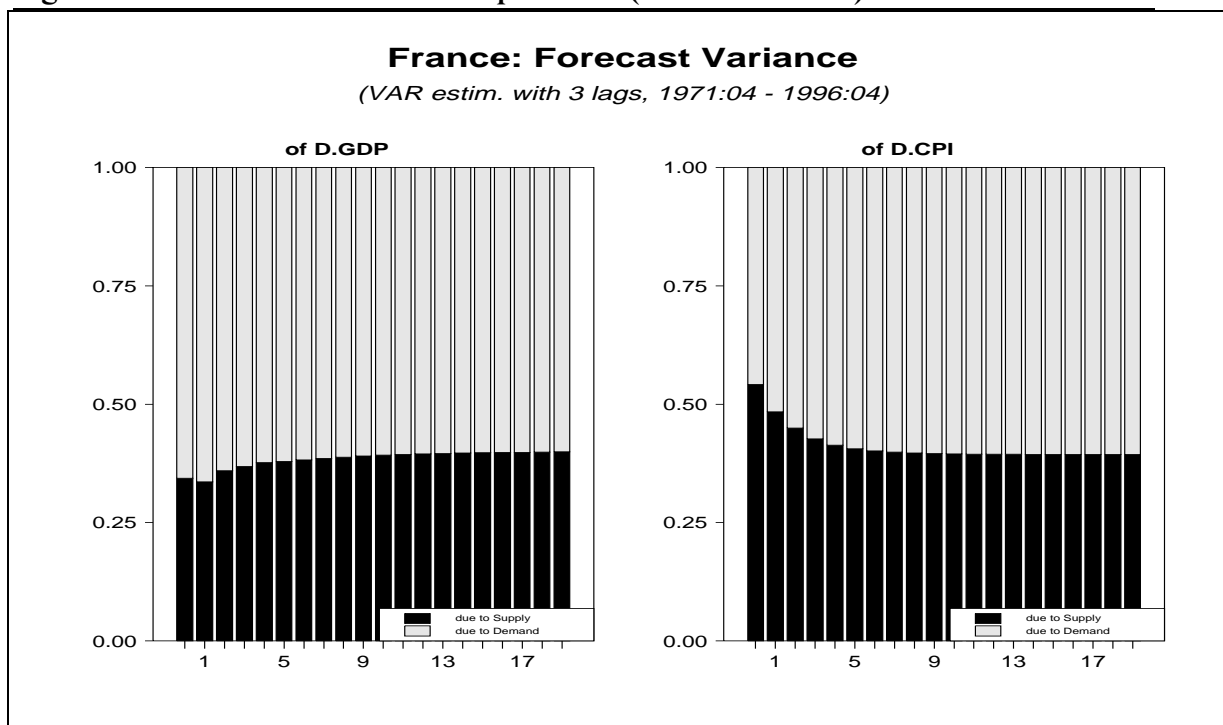
Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 22: France - Impulse Response Functions (bivariate model)



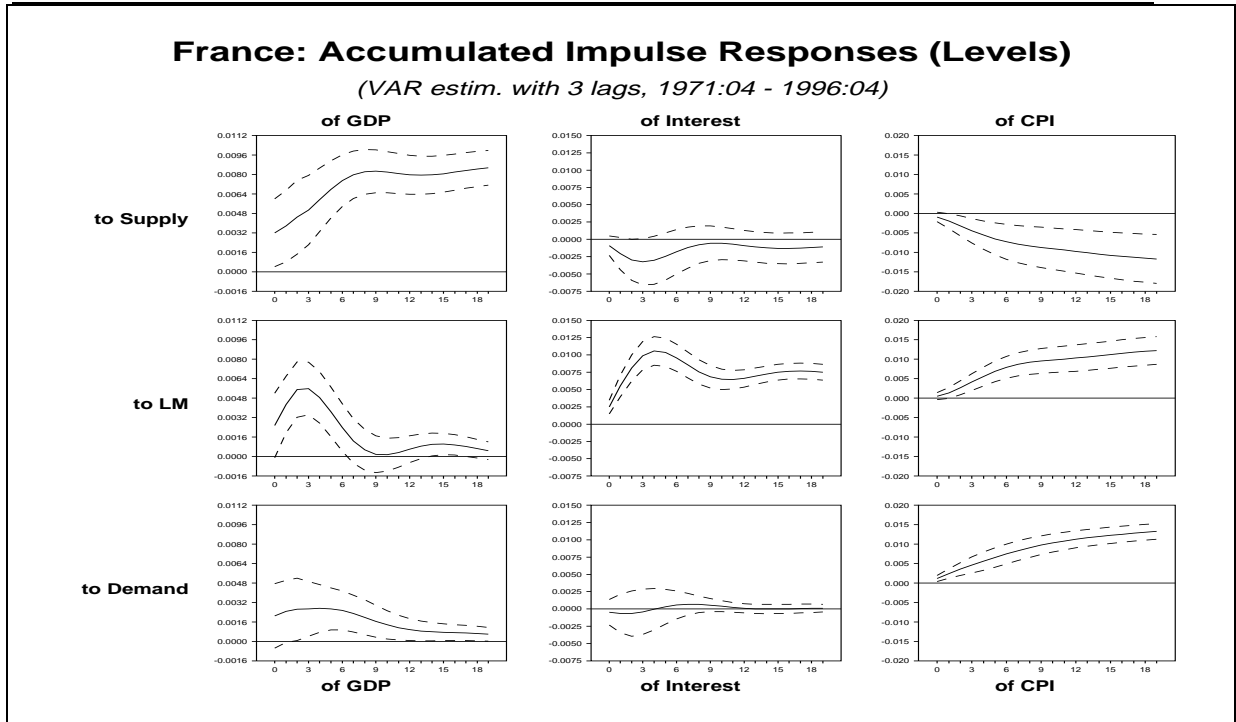
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 23: France - Variance Decompositions (bivariate model)



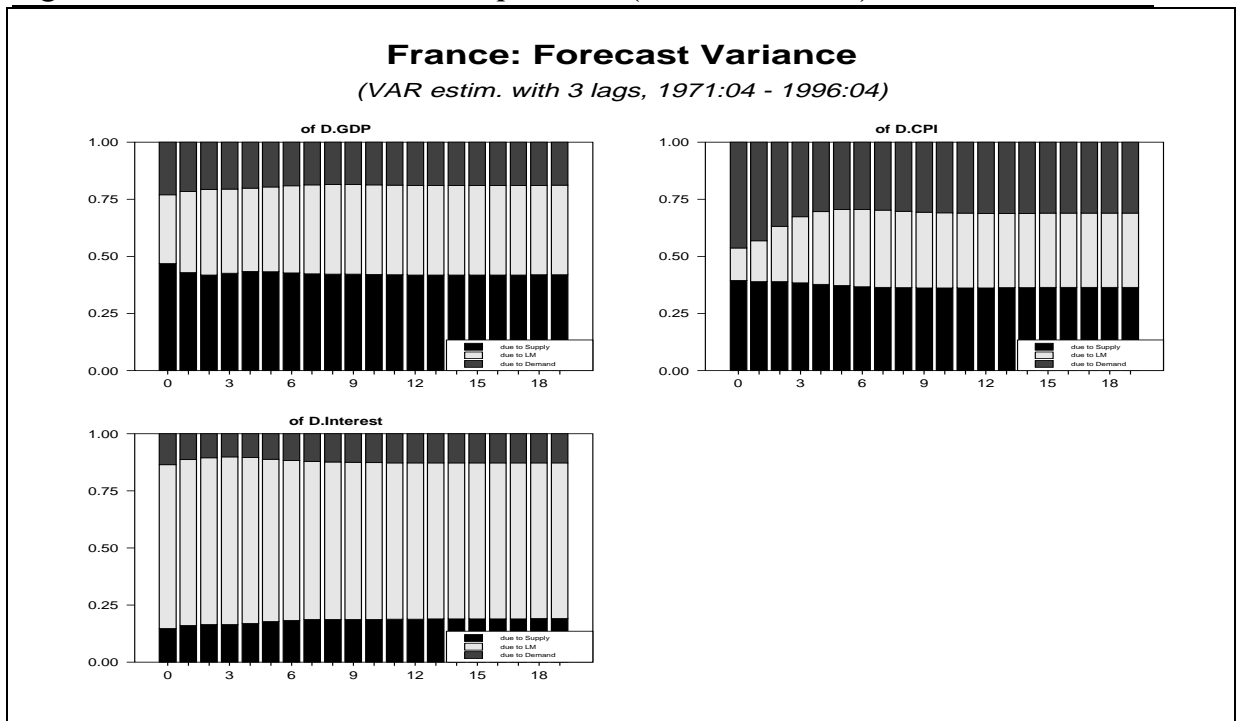
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 24: France - Impulse Response Functions (trivariate model)



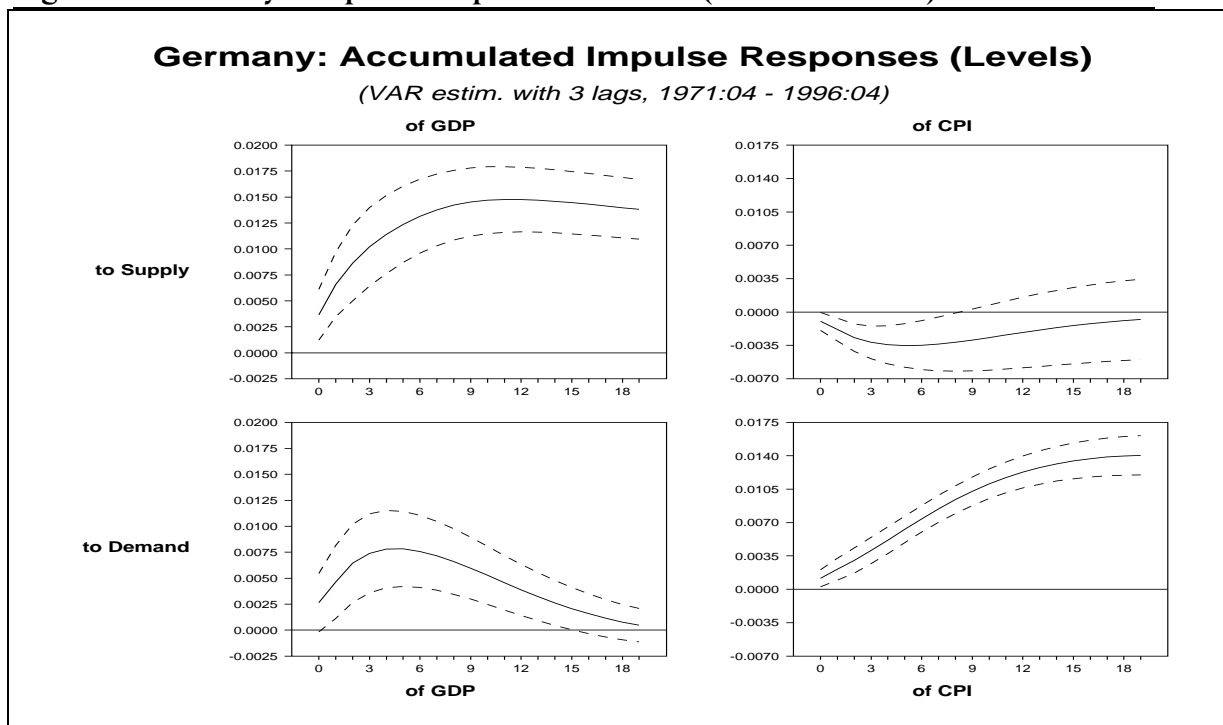
Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 25: France - Variance Decompositions (trivariate model)



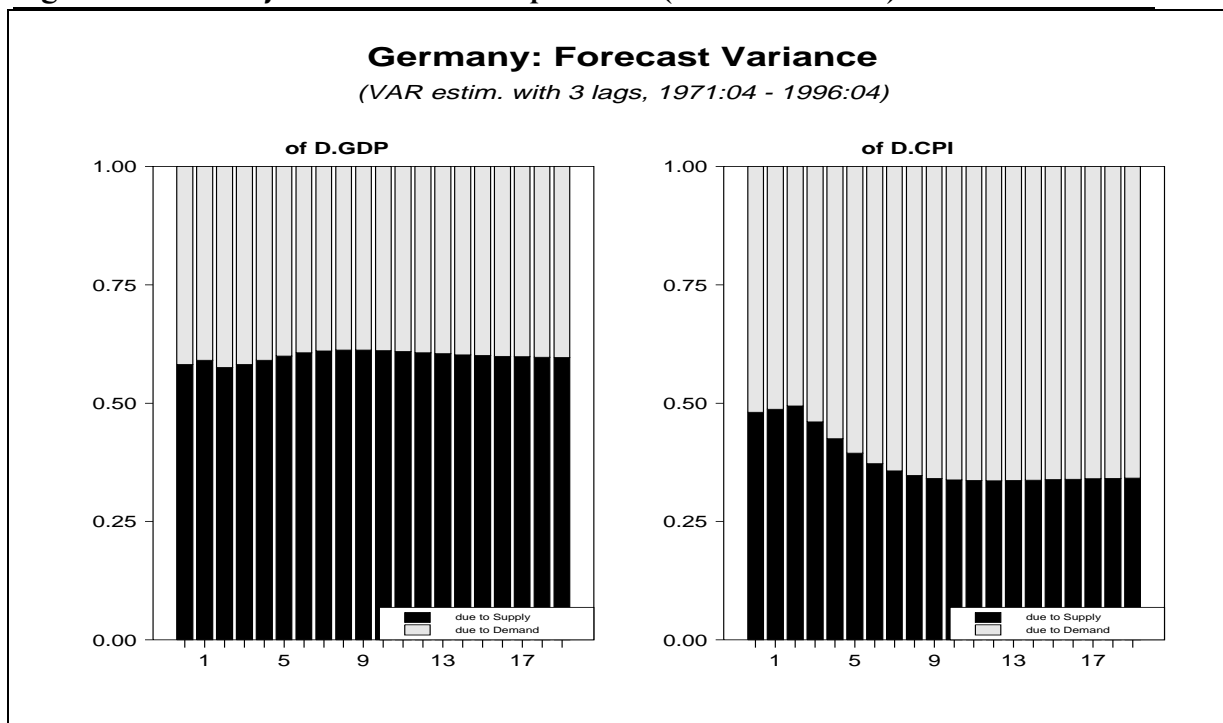
Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 26: Germany - Impulse Response Functions (bivariate model)



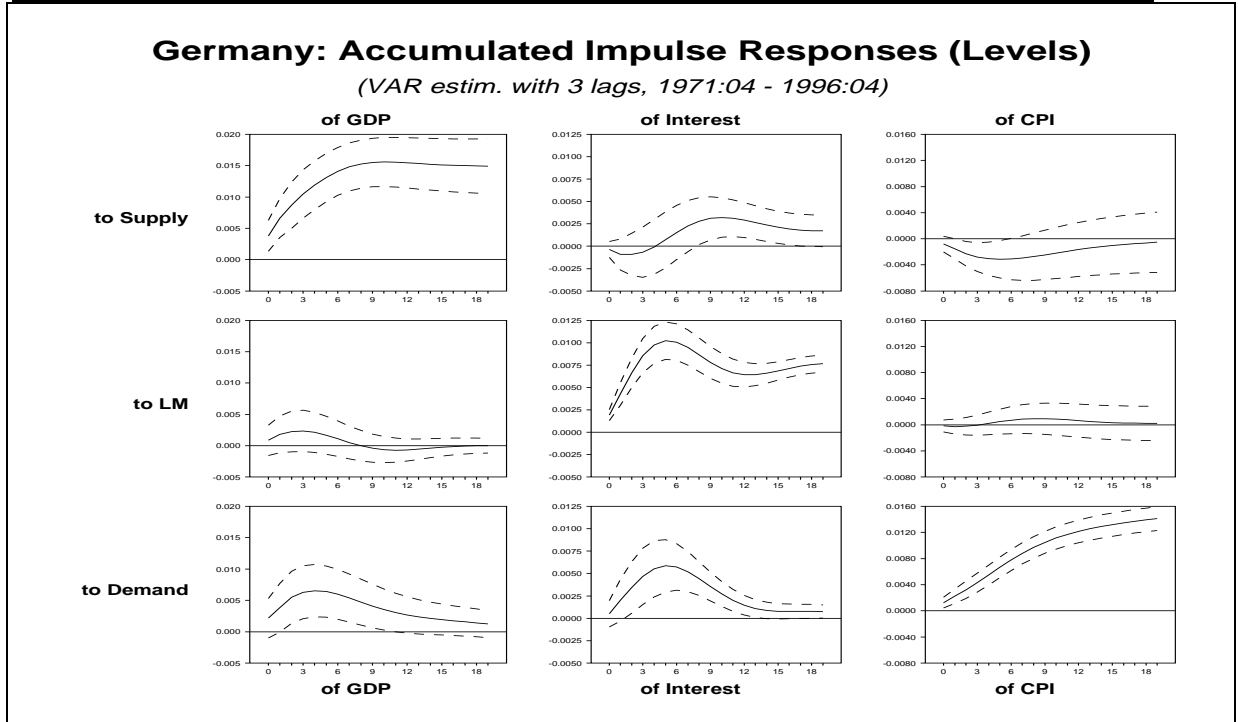
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 27: Germany - Variance Decompositions (bivariate model)



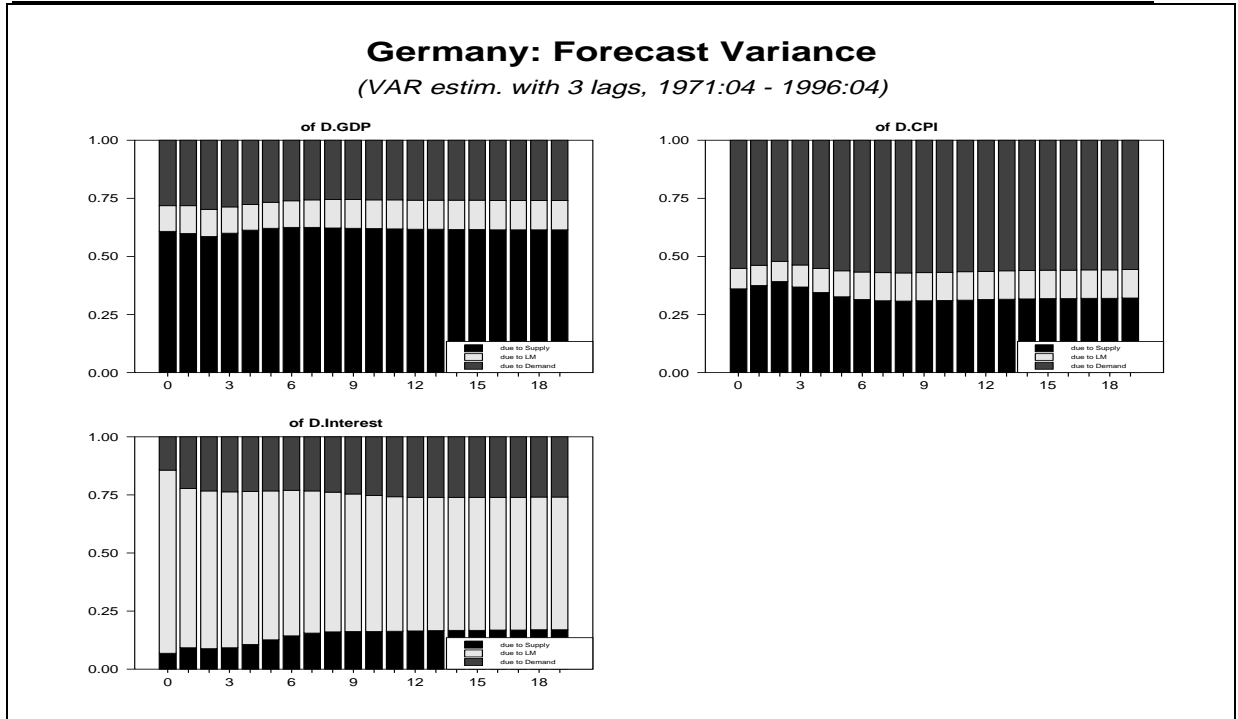
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 28: Germany - Impulse Response Functions (trivariate model)



Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

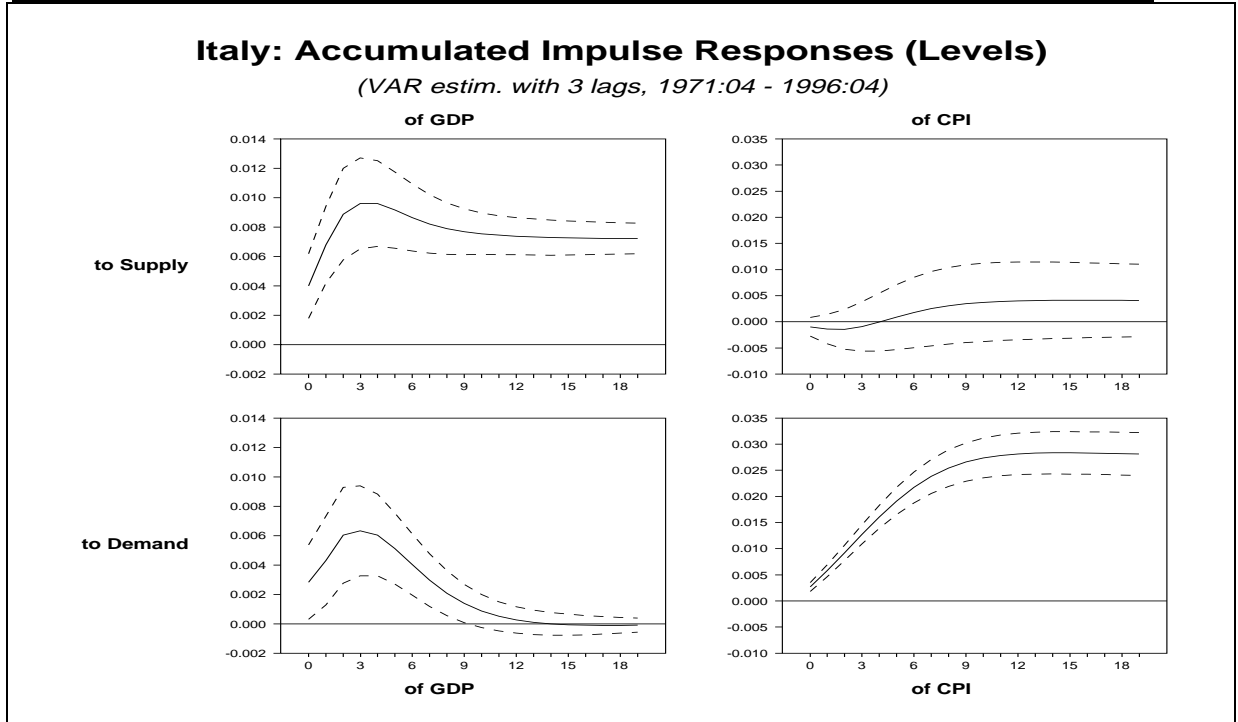
Figure 29: Germany - Variance Decompositions (trivariate model)



Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

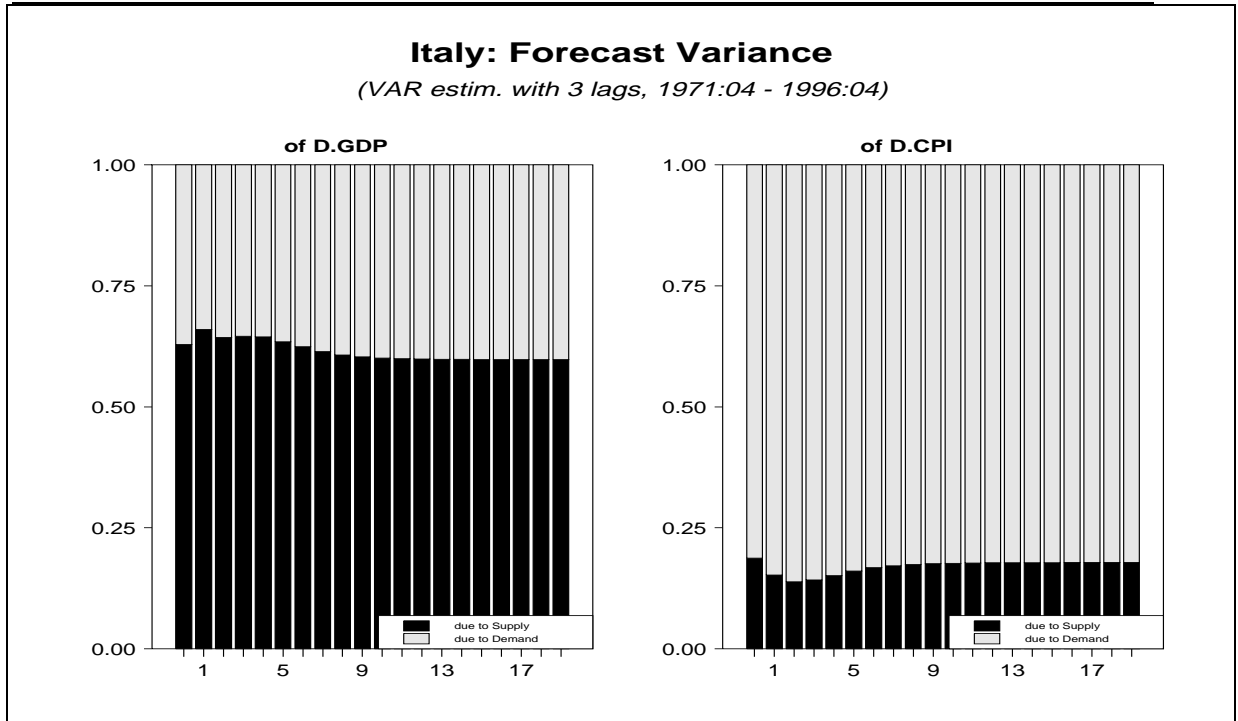


Figure 30: Italy - Impulse Response Functions (bivariate model)



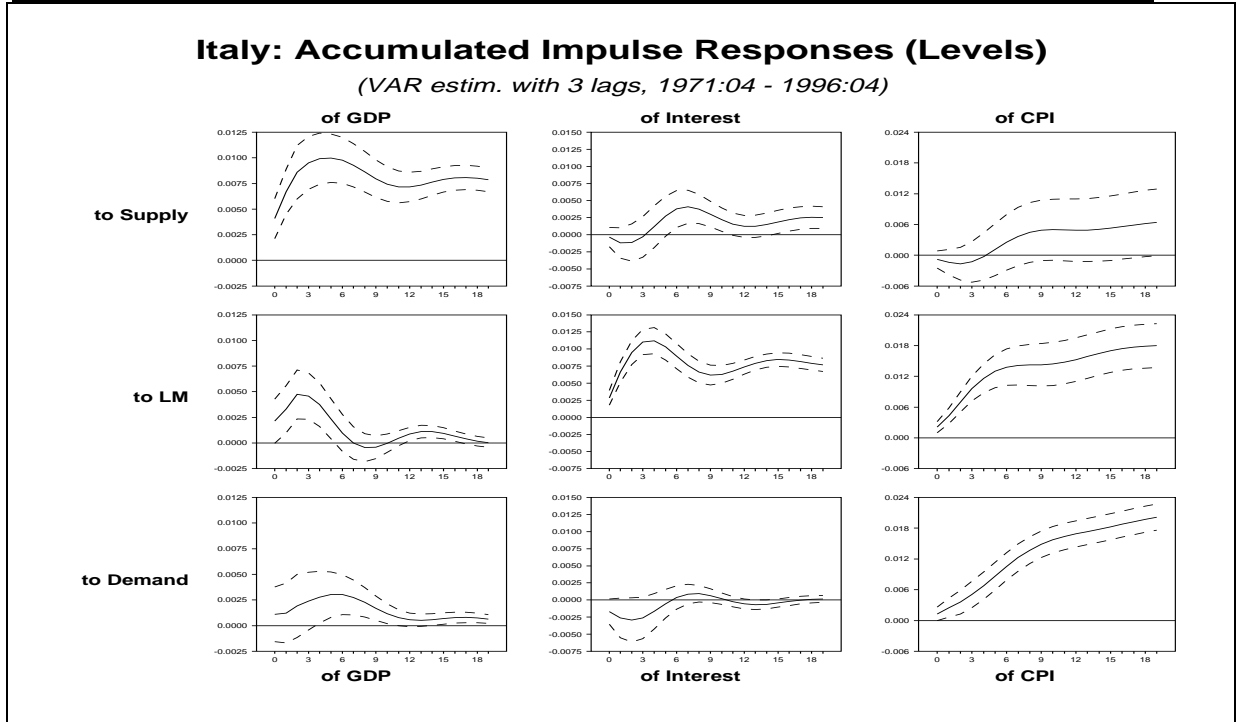
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 31: Italy - Variance Decompositions (bivariate model)



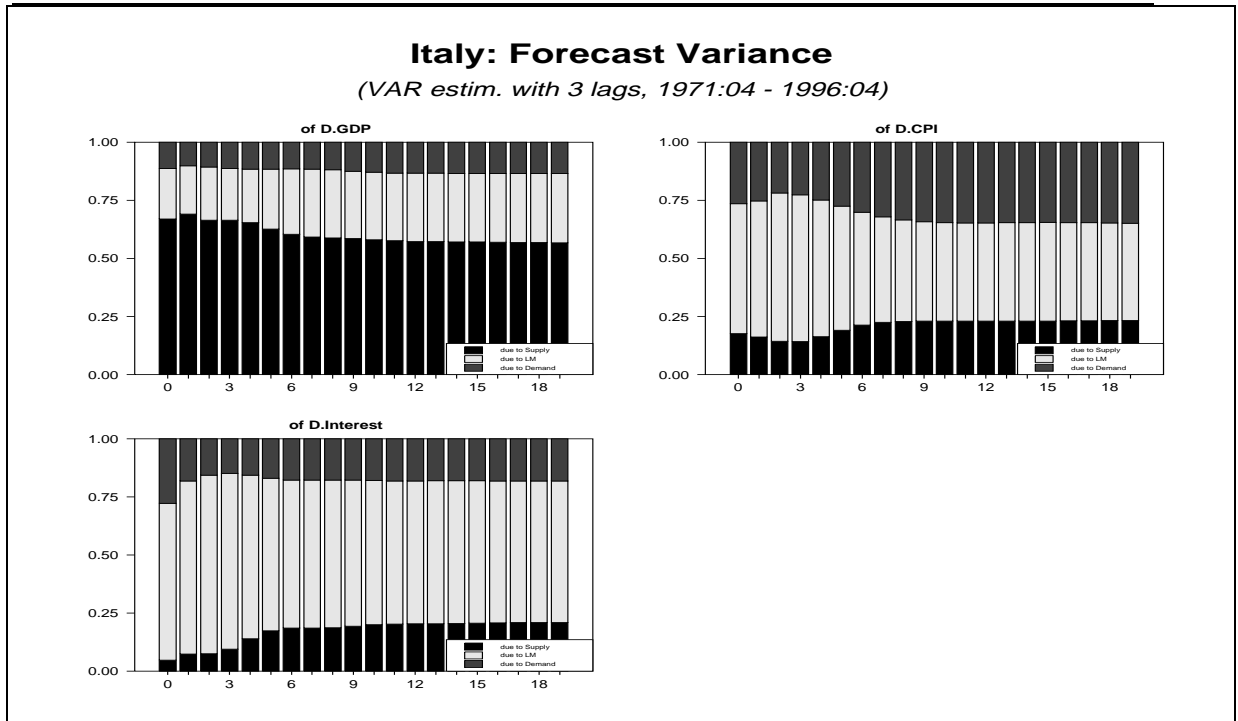
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 32: Italy - Impulse Response Functions (trivariate model)



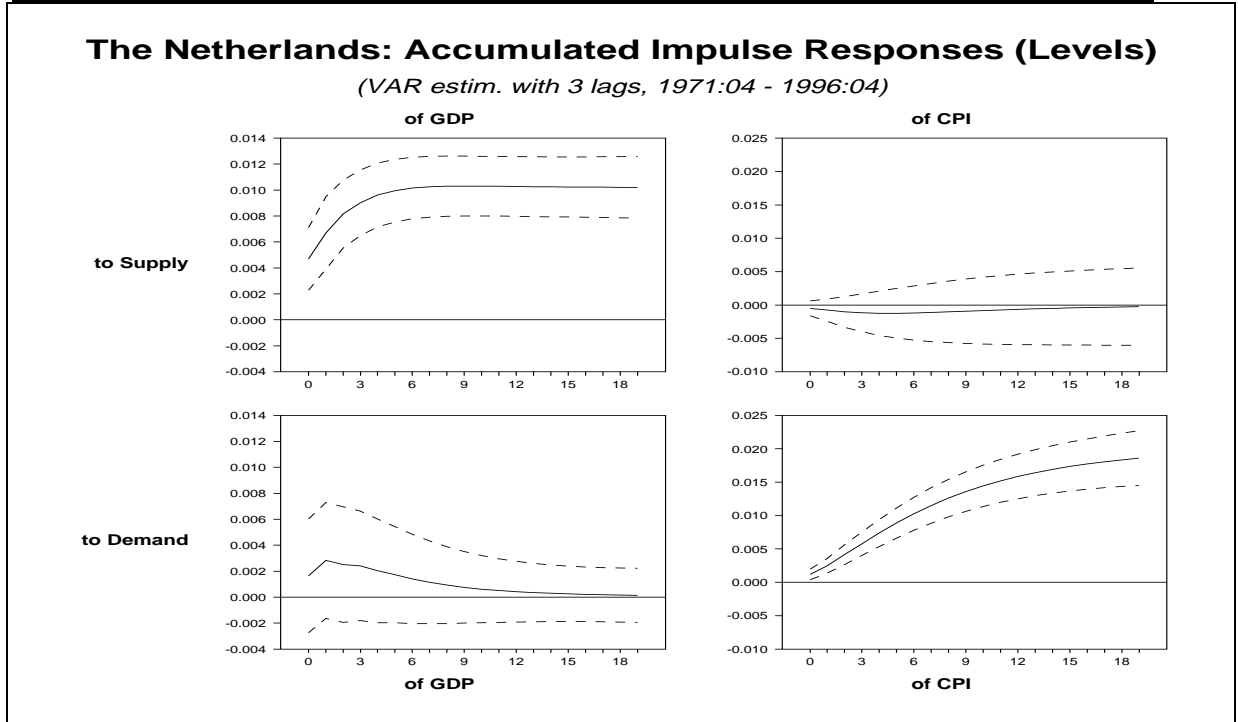
Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 33: Italy - Variance Decompositions (trivariate model)



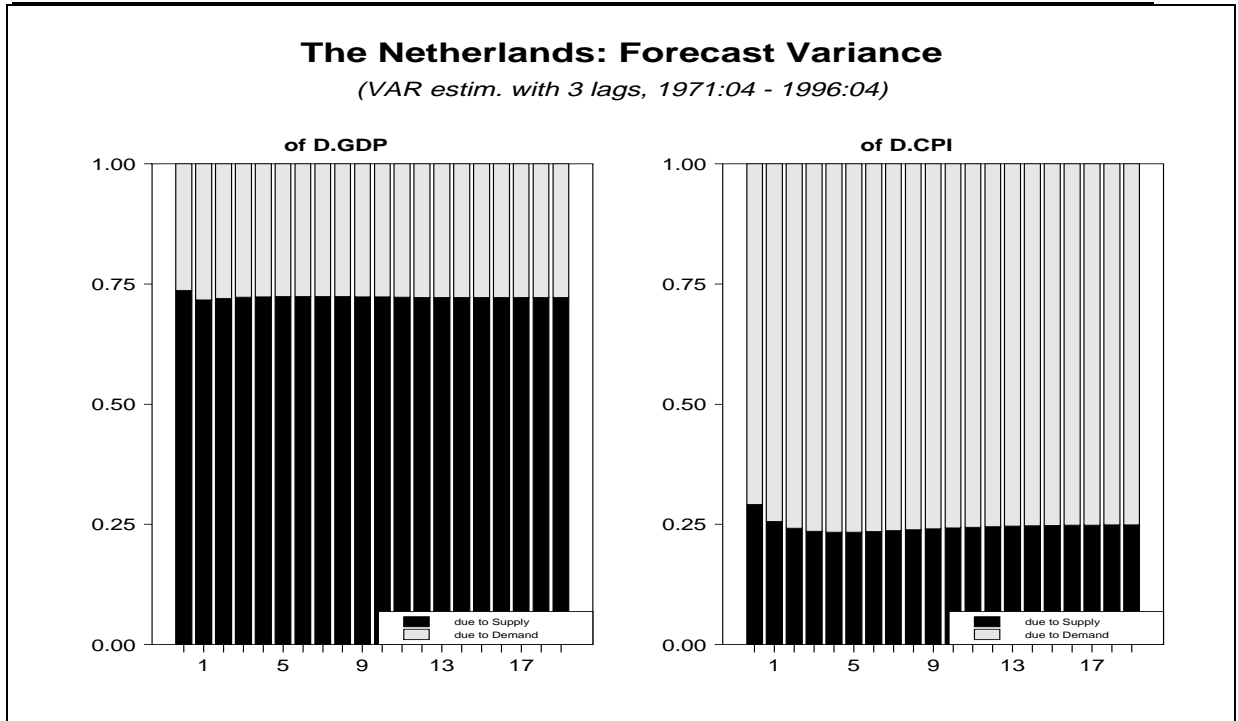
Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 34: The Netherlands - Impulse Response Functions (bivariate model)



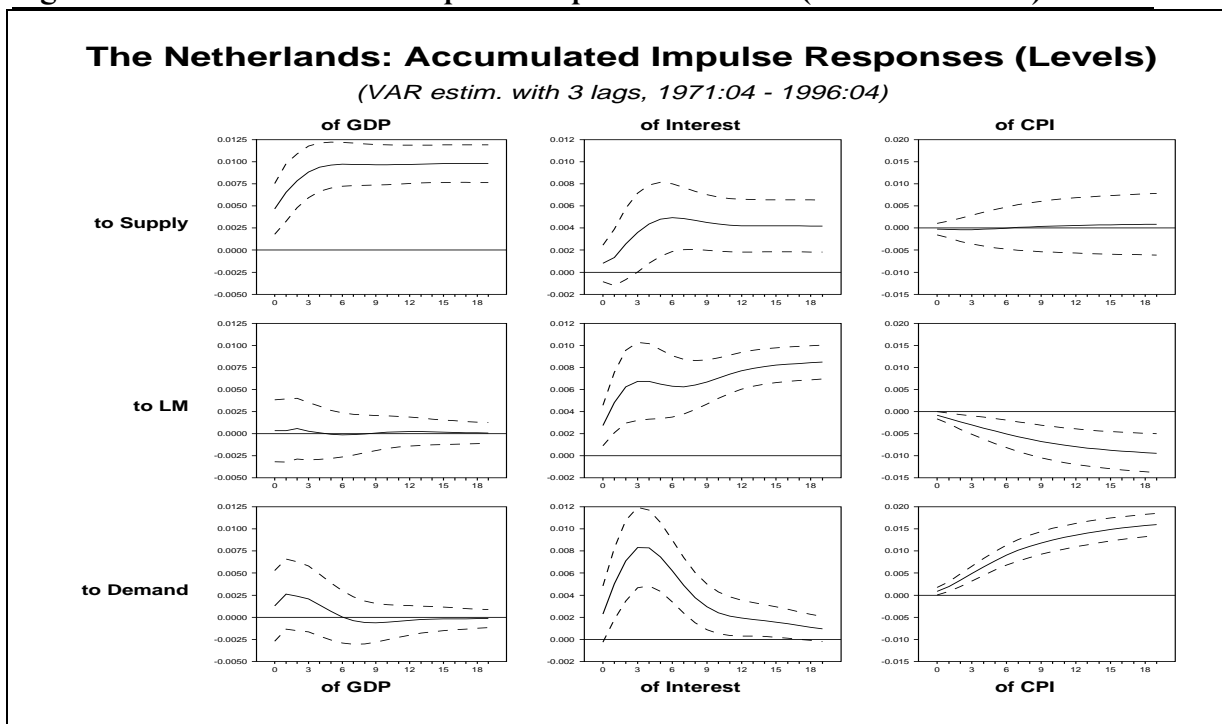
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 35: The Netherlands - Variance Decompositions (bivariate model)



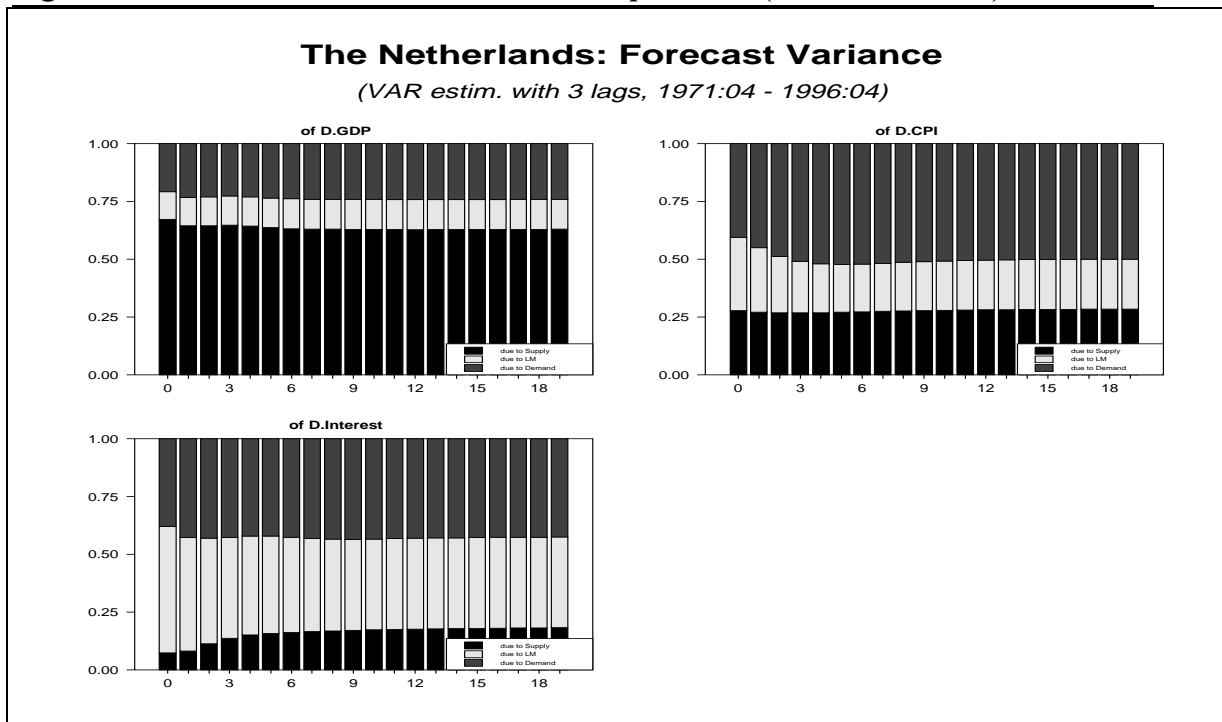
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 36: The Netherlands - Impulse Response Functions (trivariate model)



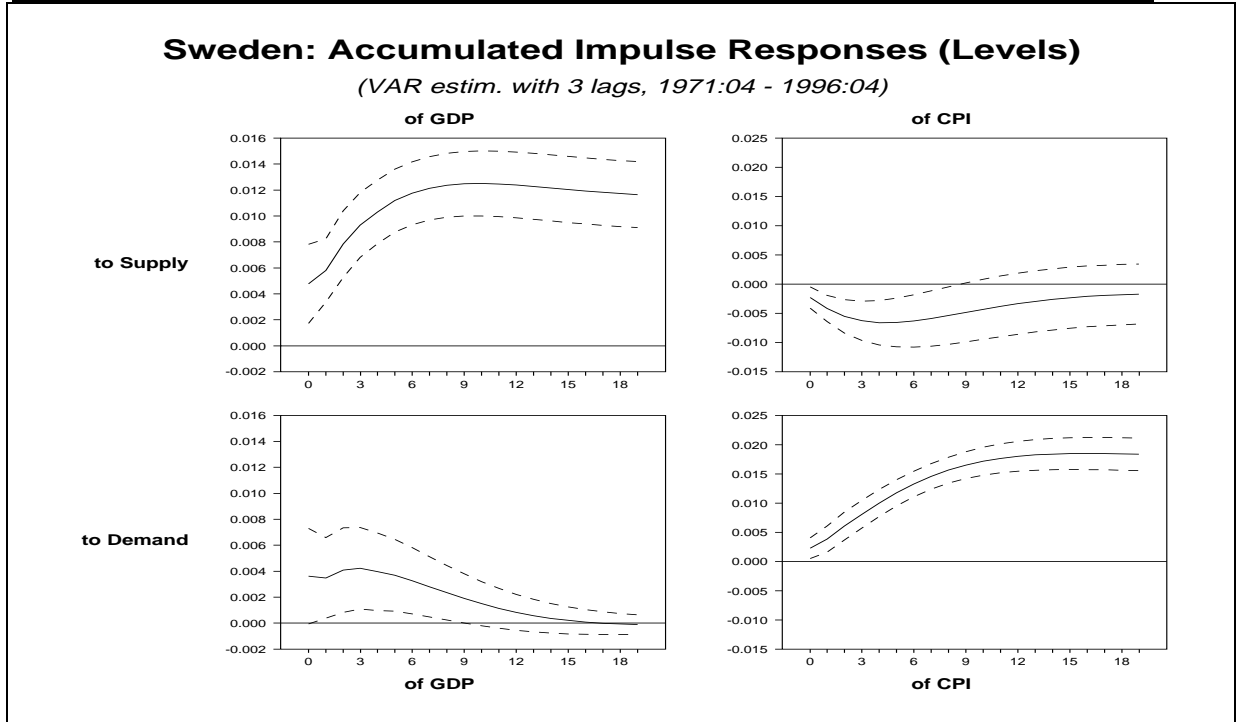
Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 37: The Netherlands - Variance Decompositions (trivariate model)



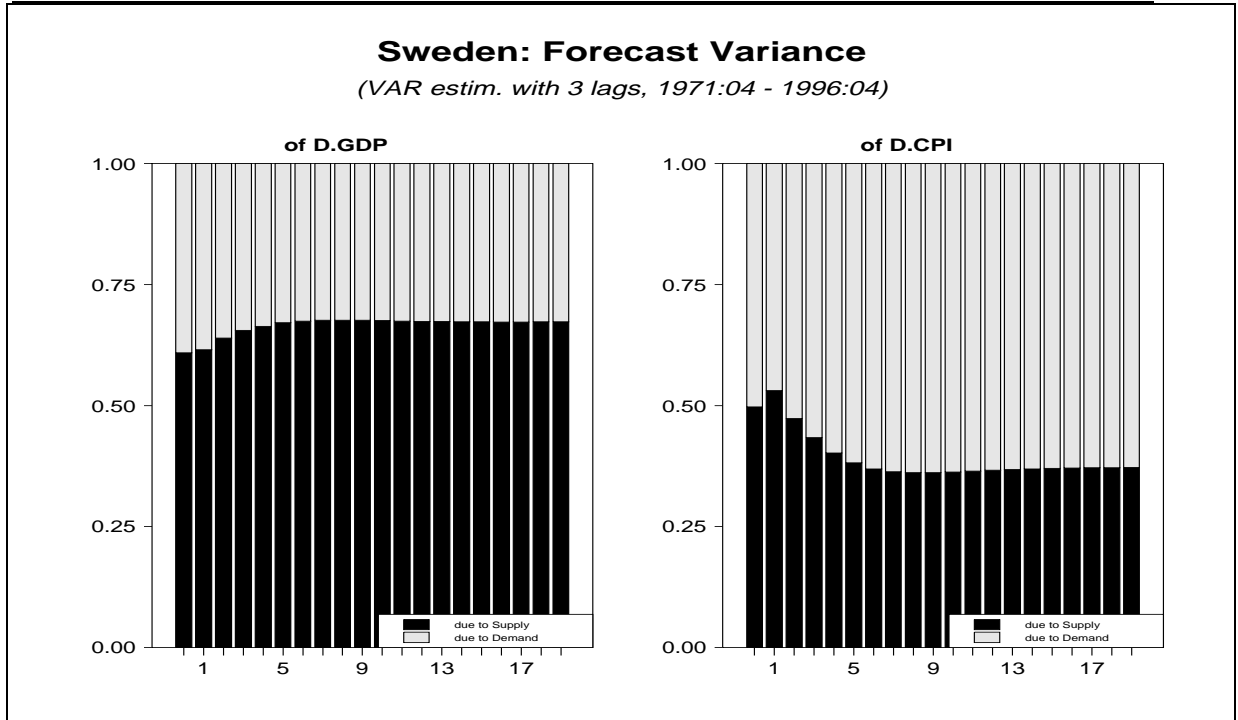
Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 38: Sweden - Impulse Response Functions (bivariate model)



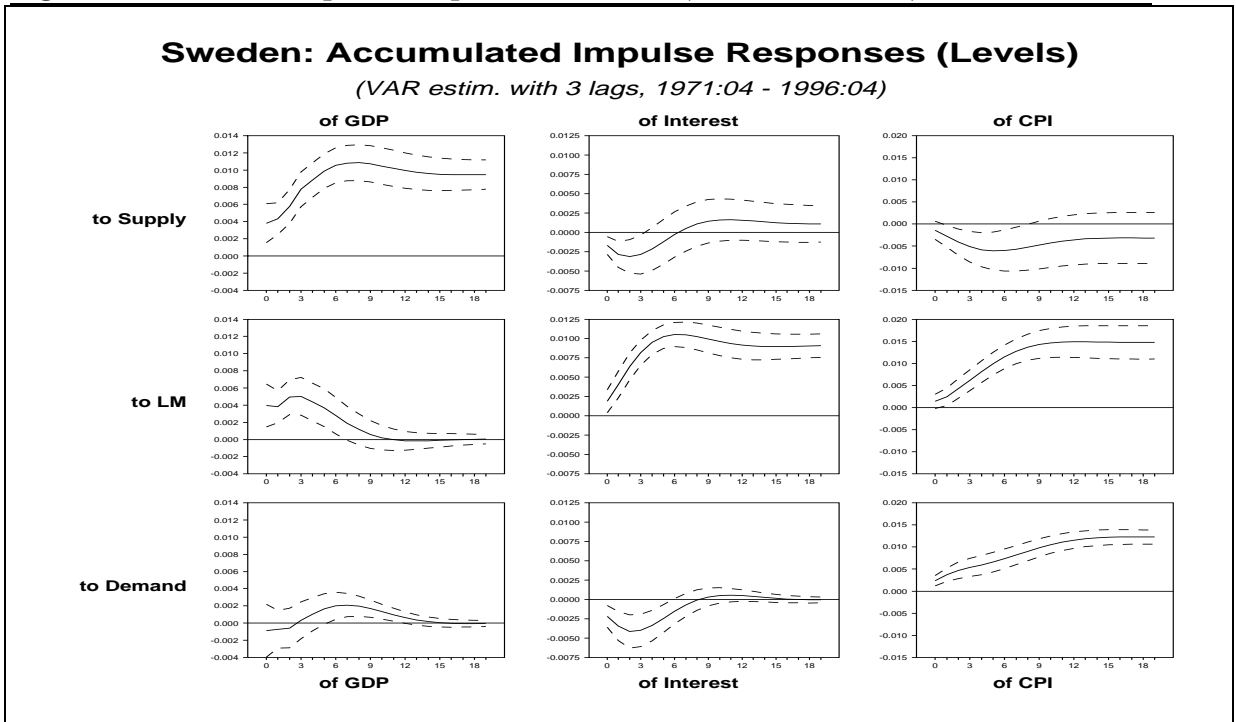
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 39: Sweden - Variance Decompositions (bivariate model)



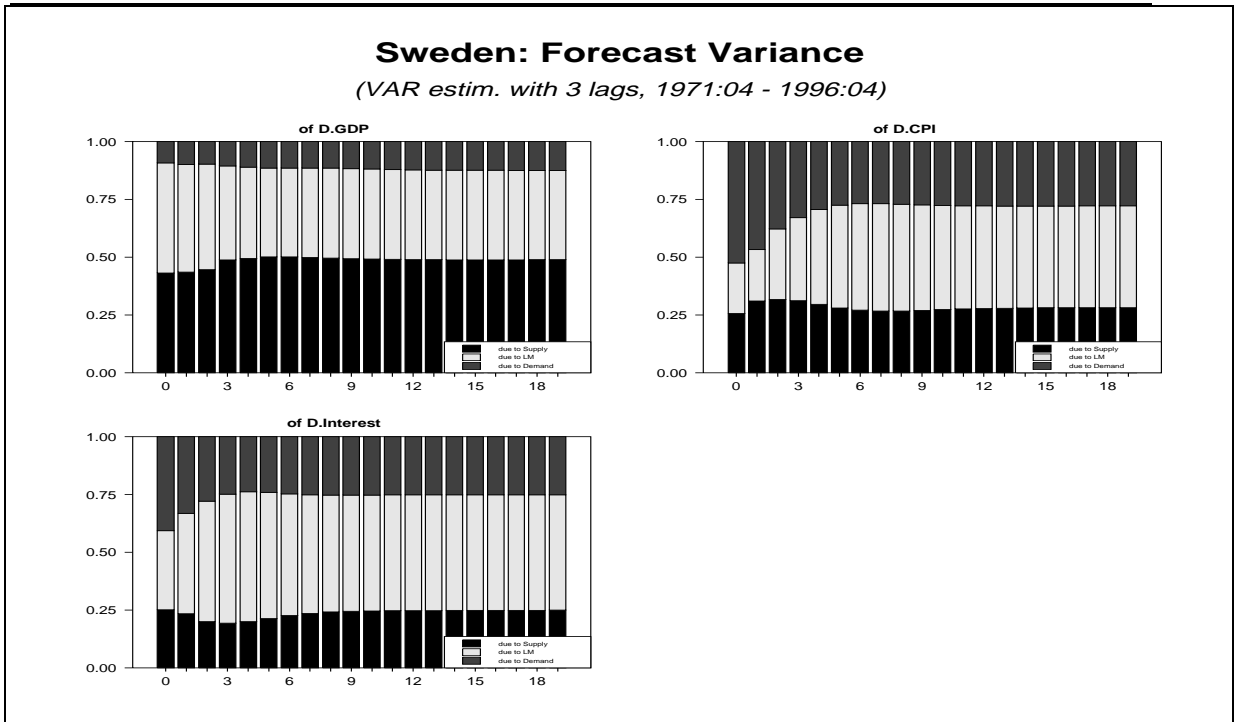
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 40: Sweden - Impulse Response Functions (trivariate model)



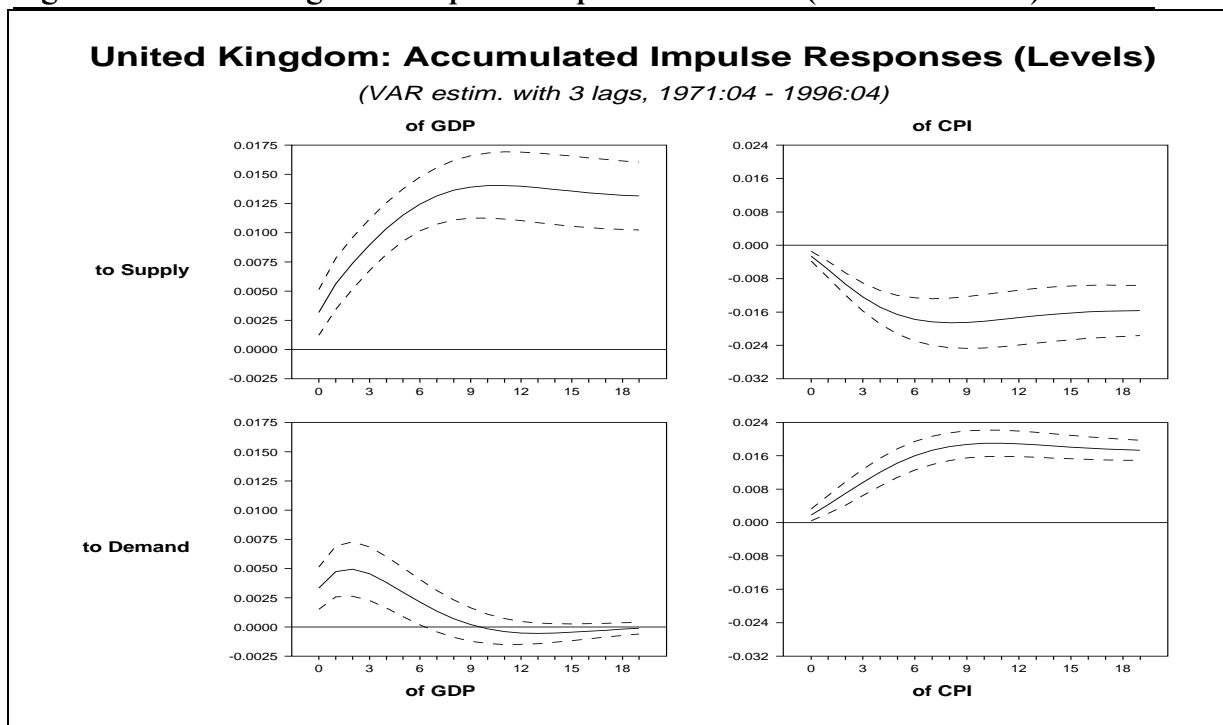
Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 41: Sweden - Variance Decompositions (trivariate model)



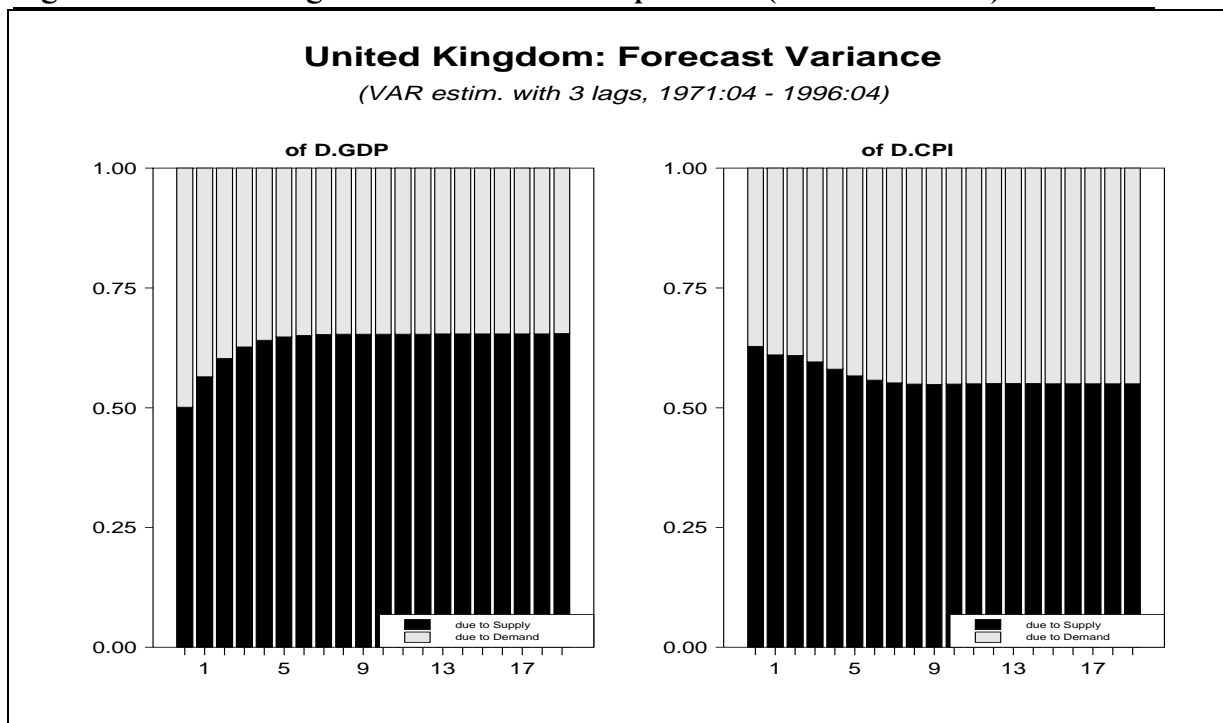
Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 42: United Kingdom - Impulse Response Functions (bivariate model)



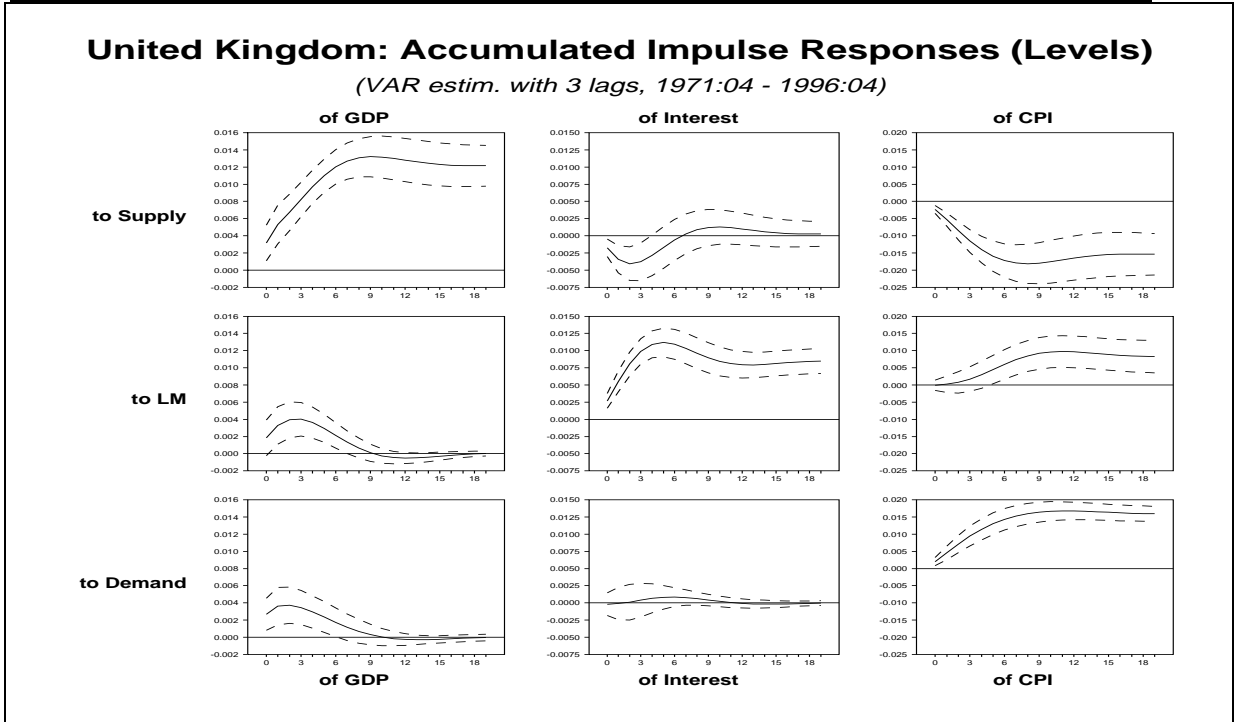
Note: Results are those of the bivariate model (output and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 43: United Kingdom - Variance Decompositions (bivariate model)



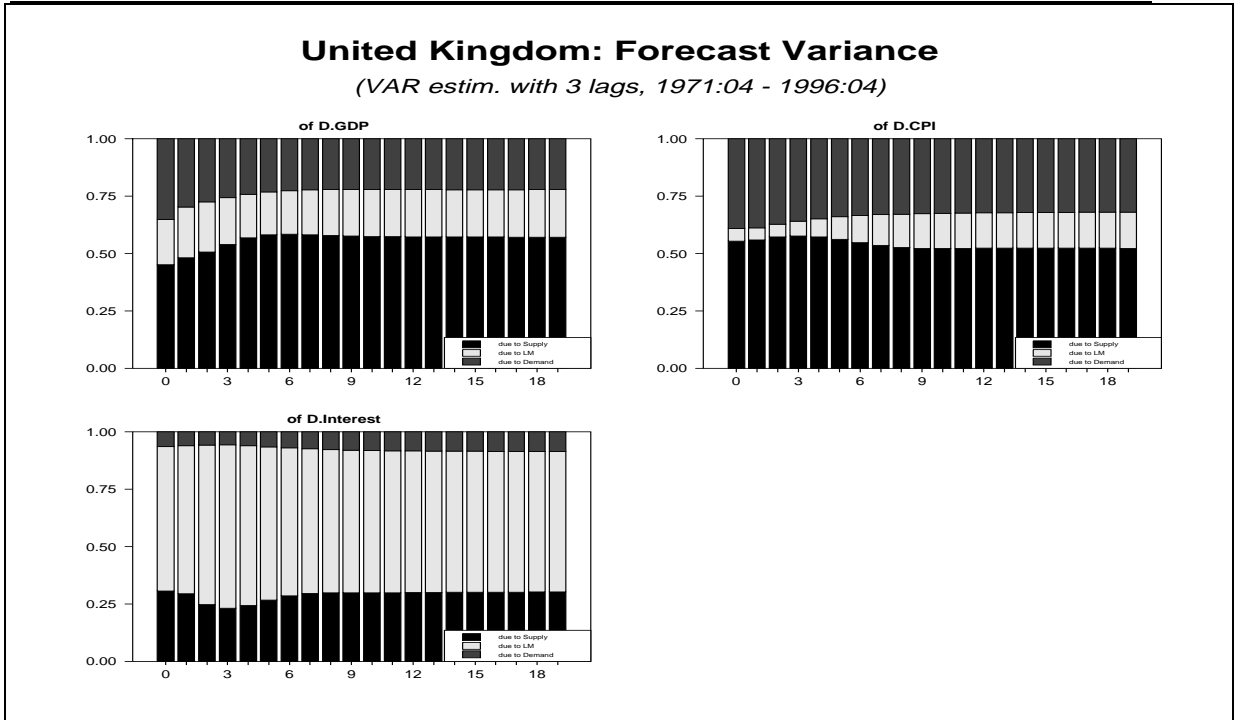
Note: Results are those of the bivariate model (output and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.

Figure 44: United Kingdom - Impulse Response Functions (trivariate model)



Note: Results are those of the trivariate model (output, interest rate and inflation). The solid lines indicate the estimated and accumulated response to the respective first period structural unit shock, dashed lines above and below are the upper and lower two standard deviation bounds computed from a simulation as described in Appendix A.

Figure 45: United Kingdom - Variance Decompositions (trivariate model)



Note: Results are those of the trivariate model (output, interest rate and inflation). The heights of the respective bars indicate the relative contribution of a specific structural shock to the forecast error variance of the respective series.