Interpretation of the information content of the term structure of interest rates

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Introduction

The objective of this paper is to analyse the information content of the term structure of interest rates in Belgium. It is, however, well known that the intermediate target of Belgian monetary policy is the stabilisation of the DM/BF exchange rate. This type of policy has produced close links between Belgian and German interest rates and therefore between both countries' term structures. Hence, the analysis of the Belgian term structure cannot be isolated from what happens in Germany and our analysis is therefore extended to include the information content of the term structure of German interest rates as well.

1. Responses of market rates to key central bank interest rates

A popular approach to the term structure of interest rates is the expectations hypothesis. According to this theory and assuming a constant risk or liquidity premium, a longer term interest rate (in terms of spot rates or spot yields) can be written as an average of an actual shorter term spot rate with given maturity and expected future values of that same short rate up to the maturity of the longer rate. The shortest available interest rate is the overnight rate, which is closely linked to the official central bank interest rate. Therefore any longer term spot rate can be written as an average of the actual and future expected values of the overnight rate. Consequently, any interest rate can, according to the expectations hypothesis, be considered to reflect market participants' expectations concerning the future stance of monetary policy. The reaction of market rates to changes in official rates may thus reveal the degree to which the market correctly anticipates future policy moves.

The reaction of market rates to changes in central bank rates may be less than proportional and decline with the maturity of the asset. Equivalently, the implicit forward rates further in the future may react less or even inversely to the change in the official interest rates. This result can be explained by two arguments: first, interest rates, and especially the official target rates, follow a mean-reverting process, so that long rates should react less then short rates. Changes in the official rates are persistent but not permanent; second, some part of the change in the official rate may already be anticipated by the market, such that even short market rates may not fully adjust to official rate changes.

It is therefore interesting to decompose the reaction of market interest rates into the anticipated component and the surprise or announcement effect, on the one hand, and to detect the degree of persistence in market expectations on the other. This decomposition can reveal how correctly the market understands the reaction function of the central bank, and whether it considers the official interest changes as permanent or as temporary. Perhaps this last issue can be interpreted as a measure of credibility. If the policy is thought to be effective, official interest rate changes (to bring a given objective of monetary policy such as inflation or, as in Belgium, the DM exchange rate, back to its target value) will be considered to be temporary in nature. If, on the other hand, the market participants consider the policy move to be ineffective or incredible, it will obtain a permanent or even extrapolative character.

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Following Roley and Sellon (1996), we consider the relation between the target value of the monetary policy objective in the following month (X_{t+1}) to be related to the actual one-month interest rate ($r_{1,t}$) and a random error term (u_{t+1}):

$$X_{t+1} = a - br_{1,t} + u_{t+1} \tag{1}$$

The random error is autocorrelated:

$$u_{t+1} = \rho u_t + \nu_{t+1} \tag{2}$$

where ν is a white noise process and ρ measures the degree of persistence of economic or financial shocks.

Market participants expect the central bank to influence the money market rate in order to hit its target of monetary policy. They therefore expect, for example, the one-month interbank rate to reflect the central bank's reaction function as:

$$r_{1,t}^{a} = \alpha + \beta\left[E(X_{t+1}) - \overline{X}\right] + \varepsilon_t \tag{3}$$

where $r_{1,t}^{a}$ is the one-month interest rate just after the policy move at the end of period t (in the empirical work this will be equivalent to the market rate the day after the official rate has changed).

From the preceding equations, the market participants' perceived move (abstracting from uncertainty) of the one-month interest rate between the end of period t-1 and the end of period t is:

$$r_{1,t}^{a} - r_{1,t-1}^{a} = \delta\left[\varepsilon_t - \varepsilon_{t-1} + \beta\rho(\rho u_{t-1} + \nu_t - u_{t-1})\right] = \Delta r_t^{o} \tag{4}$$

where $\delta = \dfrac{1}{(1+\beta b)} < 1$ and r^{o} is the official interest rate.

However, there is always a probability that the central bank does not follow its reaction function and undertakes a discretionary action. If market participants are sure that the central bank will follow its reaction function and therefore change its official rate in line with deviations between actual and target values of the central bank's objective, the market rate will anticipate such a rise before the official move:

$$r_{1,t}^{b} - r_{1,t-k}^{a} = (1-\theta)\Delta r_t^{o} \tag{5}$$

where r_1^{b} is the one-month rate just before the official rate move (in the empirical work the day before an official rate change) and θ is the probability that the central bank will not change the official rate (i.e. will act in a discretionary way).

The immediate response of the one-month market rate to the policy change (i.e. the difference between the market rate at the day after and the day before the policy move) is then:

$$r_{1,t}^{a} - r_{1,t}^{b} = \theta\Delta r_t^{o} \tag{6}$$

For longer maturity market rates the relation becomes more complicated:

$$r^a_{N,t} - r^b_{N,t} = (\frac{1}{N})\sum_{j=0}^{N-1}\theta^{j+1} * \Delta r^o_r \tag{7}$$

$$r^b_{N,t} - r^a_{N,t-k} = (\frac{1}{N}) * \left[(1-\theta) + \sum_{j=1}^{N-1}(\rho^{j} - \theta^{j+1} + (1-\rho)\sum_{i=1}^{j}\theta^{i}\rho^{j-i}) \right] * \Delta r^o_t \tag{8}$$

In the case of N=3, this becomes:

$$r^a_{3,t} - r^b_{3,t} = (\frac{1}{3}) * (\theta + \theta^2 + \theta^3) * \Delta r^o_t$$

$$r^b_{3,t} - r^a_{3,t-k} = (\frac{1}{3}) * \left[(1-\theta) + (\rho - \theta^2 + (1-\rho) * \theta\ ) + (\rho^2 - \theta^3 + (1-\rho) * \theta\ \ \rho^1 + (1-\rho) * \theta^2)\right] * \Delta r^o_t$$

Estimation over the period February 1991 (start of the new organisation of the monetary policy in Belgium) to August 1996 (the penultimate change in the official rate) results in a non-significant negative coefficient for ρ. However leaving out the period of 23rd July –15th September 1993 where the official rate was raised to defend the Belgian franc against speculative pressures, the estimates produce a significant and high value for ρ = 0.8. The changes of the central rate are thus considered by the market as persistent but non-permanent movements.

The estimation of the θ coefficient, measuring the degree of surprise (or, inversely, the degree of anticipation) of interest changes, gives far fewer problems. In all cases it is situated around 0.84 and is highly significantly. So the changes in the official rate are mostly unanticipated by the market, and the surprise or announcement effect of the change is strong. This indicates that monetary policy was the leading variable in the period under consideration and that market rates followed the official rates. This result explains why long rates on the yield curve change less than proportionally after an official interest rate change, as market participants do not consider the official interest rate move, or the fundamental economic variable that causes the central bank to react, to be permanent. The limited reaction of long rates can also be due to the presence of future lower or higher short interest rate anticipations in the long rate before the official move actually took place. This effect, although present, was less strong in our results.

The same model was estimated for Germany. The degree of persistence is estimated at 0.89, but the coefficient is significantly less then one, implying that the underlying economic shocks are perceived to be mean reverting. In other words, German monetary policy is considered to be effective in targeting its objectives. The somewhat lower value for Belgium is explained by the higher volatility of short-term interest rates. But the differences in the formulation of policy targets between Belgium and Germany makes a comparison of these parameter values quite irrelevant.

The estimate of the surprise parameter θ is very low for Germany: the probability that the Bundesbank will not change its rate is estimated to be as low as 0.12% on average. Market participants are quite convinced that the Bundesbank will follow its normal reaction function; therefore they can almost fully anticipate official rate movements. The change in the official interest rate has only a weak surprise effect on the market rates at the day of change. The low correlation between the Repo rate and the money market rates (see Table 1) on the day of change is also found in Deutsche Bundesbank (1996). In this analysis it is mentioned that the low reaction of market rates is enhanced by the use of fixed-rate tenders, implying prior announcement of the rate of interest. Furthermore, changes in the repo rate are made in small and frequent steps, which may also contribute to a lower surprise effect. Although such technical reasons contribute to the low value of the estimated parameter, the obtained strong result does seem to confirm that the Bundesbank policy is perceived by market participants to be clear and credible. To that end the Bundesbank supplements its set of monetary policy instruments with an effective information strategy which makes its policy transparent and accountable (Schmid and Asche, (1997)). The German experience demonstrates that a credible monetary policy implies a relatively low reaction of long-term interest rates to official policy moves and that the latter may, for a substantial part, be anticipated by the market participants well in advance of official interest rate changes. The term structure of interest rates may, therefore, anticipate the future policy stance of the central bank. When analysing the impact of monetary policy one should therefore clearly distinguish that part which was already anticipated by the market.

Table 1

Impact of official interest rate changes on the market interest rate

OLS and multivariate non-linear LS estimates

Change in market interest rate: day after (t) – day before (t)	**Belgium[1]: change in central rate**		**Germany: change in Repo rate**	
Overnight	0.87	(0.07)	0.33	(0.16)
1-month eurorate	0.83	(0.12)	0.15	(0.07)
3-month eurorate	0.61	(0.10)	0.13	(0.06)
6-month eurorate	0.60	(0.09)	0.15	(0.06)
12-month eurorate	0.52	(0.06)	0.23	(0.06)
2-year domestic rate	0.26	(0.05)	0.15	(0.05)
5-year domestic rate[2]	0.13	(0.04)	0.06	(0.05)
10-year domestic rate			0.01	(0.05)
Change in market interest rate: day before (t) – day after previous change (t-1)				
Overnight	0.32	(0.14)	0.68	(0.17)
1-month eurorate	0.37	(0.12)	0.79	(0.11)
3-month eurorate	0.30	(0.11)	0.80	(0.10)
6-month eurorate	0.44	(0.11)	0.76	(0.10)
12-month eurorate	0.31	(0.11)	0.74	(0.12)
2-year domestic rate	0.20	(0.12)	0.44	(0.14)
5-year domestic rate[2]	0.20	(0.11)	0.25	(0.14)
10-year domestic rate			0.12	(0.13)
Model parameters				
θ : measure of surprise	0.84	(0.02)	0.12	(0.03)
ρ : measure of persistence	0.80	(0.07)	0.89	(0.05)

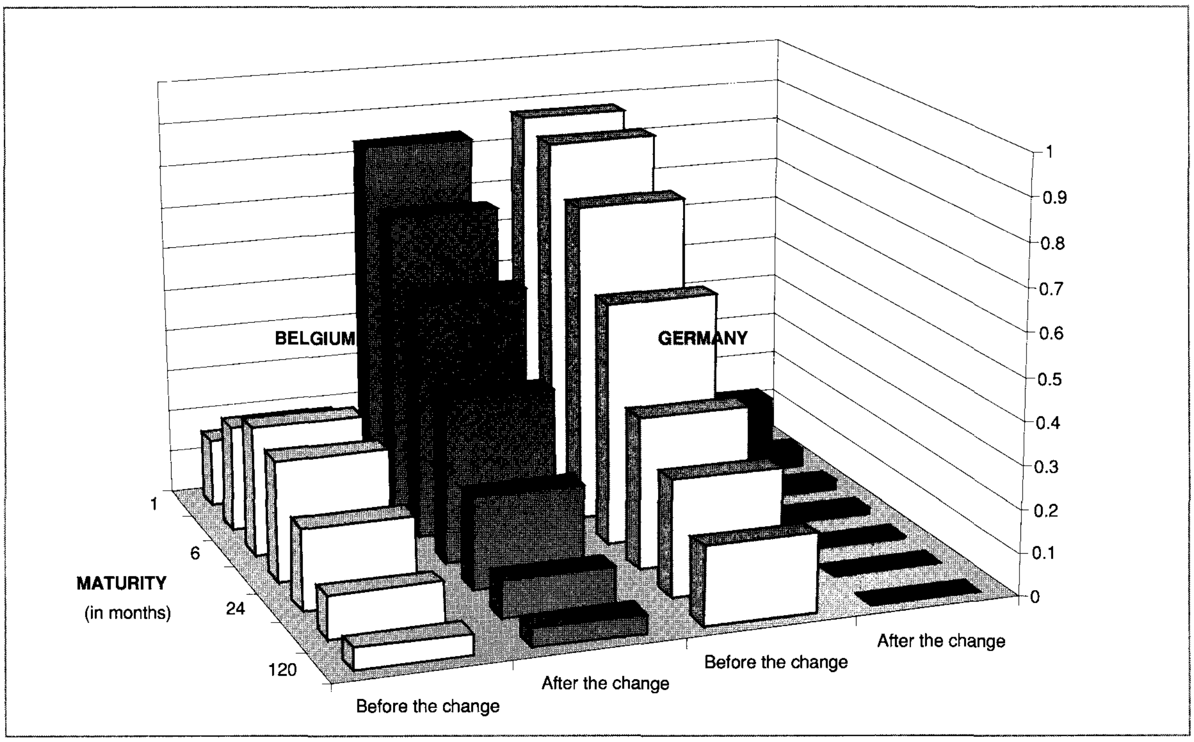
Note: Estimation period 31/1/1991-1/9/1997.

[1] Including 6 interest changes between 23/7/1993 and 15/9/1993. [2] Six years and more for Belgium.

Graph 1 differentiates surprise and anticipation effects of official interest rate changes. The higher surprise effect obtained for Belgium as compared to Germany is the result of differences in monetary policy objectives and instruments. The intermediate objective of monetary policy in Belgium is the stability of the DM/BF exchange rate. Exchange rate tensions, however, come quite suddenly and unpredictably, making the immediate response of the central bank equally sudden and non-anticipated in advance. Furthermore, in the absence of a system based on reserve requirements, banks may have less room to anticipate expected interest rate movements in Belgium.

Graph 1

Estimated term structure response to a one percentage point increase in the official rate



But, in any case, in both countries the central bank has a strong impact on the yield curve. This curve, therefore, reflects the "stance" of monetary policy as well as market expectations about future interest rates and economic conditions. This makes the interpretation of the yield curve more complicated. To derive useful information from it for monetary policy purposes, a correct interpretation of the underlying factors that explain the specific form of the yield curve at a given moment in time is needed. To that end we will try to identify the different underlying macroeconomic shocks that can be considered to be the main driving forces behind movements in interest rates, real growth and inflation. This should contribute to our understanding as to how these different shocks can explain the behaviour of the yield curve. But before doing this we first comment on the frequently observed correlations between the slope of the yield curve and future inflation and real GDP growth.

2. Correlations between term spread, growth and inflation

Monetary policy is basically forward looking. Since monetary policy actions affect the economy only with considerable lags, central banks need indicators of the future stance of macroeconomic variables such as inflation and real growth. According to the Consumption Capital Asset Pricing Model, a nominal interest rate on an asset with a given maturity should be related to the expected nominal growth rate over a time horizon that corresponds to the term to maturity of the asset considered. The difference between the yields on two assets with different maturities (that is the slope of the yield curve between two points) should therefore be correlated with the market participants' expected change in future nominal growth. The expected nominal growth rate can itself be decomposed into the expected real rate of growth and the expected inflation rate. We therefore analyse the correlation between the slope of the term structure involving assets with different maturities, on the one hand, and future changes in inflation and real economic growth on the other.

2.1 Correlations between the term structure and future inflation

We estimate the following equation:

$$\pi_t^j - \pi_t^k = \alpha + \beta\left(i_t^j - i_t^k\right)$$

where: π_t^j = average inflation between month t and j future months

π_t^k = average inflation between month t and k future months

i_t^j = interest rate in month t on an asset with j months of residual maturity

i_t^k = interest rate in month t on an asset with k months of residual maturity.

Table 2

Slope of the term structure and future inflation acceleration in Germany

***j* - *k* months**	α	β	R^2
6 - 3	0.04 (0.09)	-0.34 (0.47)	0.00
12 - 3	-0.11 (0.19)	-0.04 (0.12)	0.00
12 - 6	-0.07 (0.07)	0.09 (0.19)	0.00
24 - 12	-0.01 (0.14)	0.23 (0.22)	0.01
36 - 12	-0.14 (0.19)	0.47 (0.21)	0.07
48 - 12	-0.22 (0.29)	0.66 (0.22)	0.12
60 - 12	-0.42 (0.40)	0.87 (0.27)	0.18
72 - 12	-0.51 (0.51)	0.96 (0.30)	0.21
84 - 12	-0.66 (0.57)	1.02 (0.30)	0.24
96 - 12	-0.68 (0.61)	0.98 (0.29)	0.23
108 - 12	-0.64 (0.61)	0.94 (0.30)	0.23
120 - 12	-0.18 (0.66)	0.54 (0.28)	0.12

Notes: Estimation period 1972/I - 1996/I. Newey-West heteroskedasticity and autocorrelation-consistent standard errors for the OLS estimator are reported between brackets.

Table 3

Slope of the term structure and future inflation acceleration in Belgium

***j* - *k* months**	α	β	R^2
6 - 3	-0.03 (0.10)	-0.73 (0.47)	0.02
12 - 3	-0.05 (0.13)	-0.34 (0.27)	0.01
12 - 6	-0.04 (0.09)	-0.08 (0.34)	0.00
24 - 12	0.06 (0.10)	0.60 (0.14)	0.23
36 - 12	-0.02 (0.17)	0.80 (0.17)	0.25
48 - 12	0.03 (0.22)	0.74 (0.14)	0.21
60 - 12	-0.06 (0.27)	0.72 (0.14)	0.17

Notes: Estimation period 1977/III - 1996/II. Newey-West heteroskedasticity and autocorrelation-consistent standard errors for the OLS estimator are reported between brackets.

Tables 2 and 3 show positive correlations between inflation acceleration beyond one year in the future and interest rate differentials on assets with maturities exceeding 12 months in both Germany and Belgium. The term structure therefore does contain information on future inflation expectations (assuming that these expectations are formed rationally). This finding is in accordance with results generally found in the literature (see, for instance, Gerlach (1997) who reports results for Germany).

2.2 Correlations between the term structure and future real GDP growth

Theory predicts a positive correlation between the slope of the term structure and future real growth changes. In contradiction to this theoretical prediction, the literature rather reveals positive correlations between the slope of the term structure and future *levels* of real growth rates, instead of future *changes* in growth. We therefore estimated the following equation:

$$g_t^j = \alpha + \beta\left(i_t^j - i_t^k\right)$$

where: g_t^j = average real GDP growth between period t and j months into the future

i_t^j = period t interest rate on an asset with j months to maturity

i_t^k = period t interest rate on an asset with k months to maturity.

Table 4

Slope of the term structure and future real GDP growth in Germany

***j* - *k* months**	α	β	**R²**
6 - 3	1.83 (0.36)	2.07 (1.18)	0.06
12 - 3	1.83 (0.35)	1.41 (0.48)	0.15
12 - 6	1.87 (0.31)	2.69 (0.77)	0.20
24 - 12	1.92 (0.40)	2.24 (0.58)	0.22
36 - 12	1.99 (0.29)	1.20 (0.32)	0.22
48 - 12	2.03 (0.21)	0.92 (0.21)	0.25
60 - 12	2.20 (0.19)	0.61 (0.17)	0.17
72 - 12	2.38 (0.18)	0.36 (0.15)	0.09
84 - 12	2.45 (0.19)	0.25 (0.14)	0.06
96 - 12	2.55 (0.19)	0.14 (0.11)	0.02
108 - 12	2.70 (0.21)	0.03 (0.12)	0.00
120 - 12	2.79 (0.16)	-0.06 (0.06)	0.00

Notes: Estimation period 1972/I - 1996/I. Newey-West heteroskedasticity and autocorrelation-consistent standard errors for the OLS estimator are reported between brackets.

The results for Germany and Belgium reported in Tables 4 and 5 show positive correlations between the slope of the term structure and future growth rates both in the short and medium-term segments of the term spread. Funke (1997) found the yield spread to be a useful indicator of the probability of future recessions in Germany.

Table 5

Slope of the term structure and future real GDP growth in Belgium

j - *k* months	α	β	R^2
6 - 3	1.87 (0.37)	0.50 (1.20)	0.00
12 - 3	1.89 (0.34)	0.76 (0.39)	0.05
12 - 6	1.89 (0.31)	1.94 (0.78)	0.11
24 - 12	2.30 (0.41)	1.66 (0.80)	0.17
36 - 12	1.98 (0.36)	1.43 (0.33)	0.26
48 - 12	1.86 (0.25)	1.33 (0.16)	0.52
60 - 12	2.07 (0.31)	0.42 (0.12)	0.03

Notes: Estimation period 1977/III - 1996/II. Newey-West heteroskedasticity and autocorrelation-consistent standard errors for the OLS estimator are reported between brackets.

3. Interpretation of the leading character of the term structure

The joint finding that the term spread is a leading indicator for future growth and inflation but that, at the same time, it can be strongly influenced by monetary policy actions is a quite relevant point when discussing the usefulness of the term spread as an indicator for monetary policy. Indeed, when the central bank interprets changes in the slope of the yield curve as an indicator of market expectations and acts on the basis of this indicator, but in doing so itself, affects the slope of the yield curve, policy instability may result.

It is therefore important to distinguish the shocks in the term structure that are induced by monetary policy actions themselves from the shocks that are generated by new and unanticipated events in the rest of the economy. If monetary policy actions are dominant, the term structure is primarily an indicator of the stance of monetary policy. It is only as far as the shocks elsewhere in the economy are relatively important that the term structure becomes a relevant information variable that should be taken into account when deciding on monetary policy actions. If that is the case, then a further step is required enabling the central bank to identify the underlying cause of the change in the slope of the yield curve, because the direction of a monetary policy reaction should depend on the nature of the particular shocks.

It is now generally accepted that the usefulness of the term spread as an information source for monetary policy heavily depends on the interpretation of the predictive power of the yield curve. In this respect, some authors have stressed the need for a structural interpretation of the term structure, and have pointed to the dangers that could result from a wrong interpretation of these signals (see, for example, Woodford (1994)). Different theoretical structural explanations are available to explain the predictive power of the term spread :

- the term structure can predict future interest rates, growth and inflation because it reacts nearly instantaneously to macro-economic shocks that drive the business cycle in the economy. The long rate can jump upwards if economic agents see the economy starting a growth phase that will lead to strong investment and credit demand and eventually, when full capacity is reached, will result in higher inflation. This reaction of the term structure to macro-economic shocks also anticipates the normal effect of the business cycle on monetary policy and on the financial behaviour of other sectors in the economy. Once capacity constraints start to increase and inflationary pressure builds up, monetary policy becomes more restrictive, flattening the yield curve. This will be followed by lower growth and inflation as the economy enters the downward phase of the cycle. In this channel, the observed correlation between the slope of the yield curve and future growth and inflation essentially reflects the reaction of monetary policy to movements in the business cycle;

- an alternative interpretation concentrates on the effects of monetary policy on the business cycle. Under this hypothesis the predictive power of the term spread reflects the impact of the short rate on future economic development. Both price rigidity in goods and labour markets and capital market imperfections (either in the form of imperfect substitution between financial assets and/or liabilities or in the form of imperfect distribution of liquidity over different sectors) explain why a monetary policy shock may have a transitory impact on real output and inflation. Under this hypothesis the information content of the spread about future inflation and growth, is due to lagged effects of innovations in the short-term interest rate;
- a third interpretation explains the "unique" predictive power of the term spread by the specific information that the spread contains on market expectations about future interest rates and the underlying determinants, like inflation and real growth. Under this hypothesis the information in the term structure is incorporated in the innovations in the long-term interest rate, which, under this hypothesis, is thought to be much more sensitive to expectations than short-term rates. Innovations in the long rate can reflect innovations in the expected real rate, in the expected inflation rate or in the risk premium:
- in a general equilibrium context, the consumption capital asset pricing model implies that economic agents determine the growth path of their consumption expenditures as a function of the real interest rate. A steep yield curve may therefore indicate an expected increase in the real growth rate of consumption over time;
- the long rate can also move in anticipation of an expected inflation shock. Such expectations can influence the behaviour of economic agents in the process of price and wage formation and create a self-fulfilling mechanism;
- finally, the long rate can increase when investors require a higher risk premium which can result both from an increase in the price of risk (higher degree of risk aversion) or from a deterioration in the perception of macro-economic fundamentals.

These alternatives but not necessarily mutually exclusive channels of the observed leading properties of the term spread are probably closely interrelated. The movements in the long-term rate can reflect "pure" shocks in the anticipation of economic agents but they may also be induced by adjustments to shocks occurring to other variables that drive the long rate. The same applies to the short-term rate: part of the movements in the short rate can be classified as the normal expected reaction of monetary policy to growth and inflation prospects, whereas the remaining part may be due to pure unexpected shocks, which may influence future business cycle movements.

3.1 Granger causality tests

As a first approach to distinguish these channels, we estimated dynamic equations for GDP growth and inflation in terms of own lags and lags of short and long-term interest rates, allowing us to perform Granger causality tests. Significant interest rate coefficients imply that the rates contain information that is not already available in the lags of inflation or growth. Also, the specific contribution of short-term versus long-term interest rates can be evaluated. Investigating the significance of each of these interest rates should indicate whether innovations in the short or the long rate or in both are the principal reasons behind the leading character of the spread.

Before discussing these results we should mention that in what follows we have always maintained the hypothesis that the variables used are stationary. For the German data this hypothesis is statistically confirmed, whereas Belgian inflation and interest rates are possibly non-stationary (Table 6). Repeating the causality tests using first-differences for potentially non-stationary series did not change any of the conclusions of the following tests. Therefore we do not report results with first differenced variables

Table 6

Unit root test (Augmented Dickey Fuller)

	Germany	**Belgium**	**Difference: Belgium – Germany**
GDP growth	-11.59**	-8.49**	-10.26**
CPI inflation	-3.02**	-2.02	-3.30**
Short-term interest rate	-3.75**	-2.29	-2.79*
Long-term interest rate	-2.97**	-1.57	-1.59
Term spread	-3.66**	-4.15**	-3.41**

Notes: Sample period: 1970:1 - 1997:1 – quarterly data (1972:1 - 1997:1 for Belgian GDP). **(*) indicates significance at the 5% (10%) level.

Table 7 reports the marginal significance levels of interest rates in the dynamic equations for GDP growth and inflation. For Belgium the results indicate that the short-term interest rate has a stronger predictive power as compared to the long-term interest rate, but both rates are hardly statistically significant in the GDP equation and not at all in the inflation equation. This result contrasts with the significant result in the simple expectation tests for both growth and inflation as discussed above. The diverging results can be explained by the different forecast horizon of both tests, different measures of the term spreads, and restrictions that are implied by empirically estimating the theoretical expectations hypothesis. The marginal influence or contribution of the domestic interest rate shocks to the real economy do not seem to be statistically very strong according to this test.

The results improve somewhat if we also introduce the German interest rates into the Belgian equations. Lags of the German short-term interest rate have a significant influence on both GDP and inflation in Belgium. Again the long rate performs less well, and only the domestic long rate is significant in the GDP equation. The finding that the German short-term interest rate tends to dominate the domestic interest rate, does not need to surprise. The domestic interest rates are "disturbed" by the short-term volatility of the exchange rate and the reaction of monetary policy to exchange rate shocks. As these disturbances have often been temporary in nature, they should not have had a strong impact on economic activity. This weak impact of domestic short interest rates is also confirmed by the results from the study of the transmission channel of monetary policy in Belgium (see Dombrecht and Wouters (1997)). As the German short-term interest rate is less disturbed by such short-term volatility effects, it is a better measure of the more permanent shocks that matter more for economic activity. The significance of the German interest rate may also capture an indirect effect. As the German short rate is important for German output and inflation, this will spill over to Belgian growth and inflation through bilateral trade. The effect of the German short rate on German growth and inflation is indeed confirmed by the data. The long-term interest rate is also less significant in Germany.

This first result seems to indicate that, to a large part, the often found leading character of the term spread disappears when past business cycle movements are included in the information set. Only the short-term interest rate seems to contain "exogenous" or innovating shocks that affect the future course of growth and inflation. This suggests that especially the monetary policy impact on future activity gives the interest spread its unique predictive character. Innovations in expectations that are present in the long-rate movements, do not significantly Granger cause future economic activity.

Table 7

Marginal significance levels of the short and long-term interest rates for forecasting GDP growth and inflation

Dependent variables	No. of lags	Short rate DM	Long rate DM	Short rate BF	Long rate BF	German GDP growth	German CPI inflation	Belgian GDP growth	Belgian CPI inflation
Germany									
GDP growth (quarter)	1 – 5	0.02	0.45			0.00	0.08		
CPI inflation (quarter)	1 – 5	0.05	0.16			0.26	0.00		
Short rate DM	1 – 5	0.00	0.14			0.48	0.14		
Long rate DM	1 – 5	0.97	0.00			0.95	0.10		
Belgium: domestic interest rates									
GDP growth (quarter)	1 – 4			0.06	0.10			0.39	0.85
CPI inflation (quarter)	1 – 4			0.18	0.78			0.37	0.00
Short rate BF	1 – 4			0.00	0.07			0.74	0.10
Long rate BF	1 – 4			0.74	0.00			0.90	0.28
Belgium: domestic and German interest rates									
GDP growth (quarter)	1 – 4	0.01	0.20	0.21	0.04			0.05	0.74
CPI inflation (quarter)	1 – 4	0.00	0.02	0.30	0.60			0.90	0.04
Short rate BF	1 – 4	0.02	0.99	0.04	0.31			0.82	0.37
Long rate BF	1 – 4	0.07	0.78	0.25	0.00			0.76	0.27

Notes: Sample period : 1970:1 - 1997:1 – quarterly data. For each forecasted variable, the entries give the marginal significance levels (p-values) for omitting all lags of the variable indicated in the column heading from an unrestricted OLS equation that also included a constant and *n* lags of growth and inflation. P-values not greater than 0.05 indicate statistical significance. The number of lags was selected, based on the absence of autocorrelation and the significance of the last lag starting from 12 lags.

The results also correspond with those of Estrella and Mishkin (1997). They find that for Germany the predictive power of interest rates is fully captured by the short-term interest rate and that the term spread as such does not contain extra information about economic growth. But they do not make a similar test for inflation. Their results for the United States, on the contrary, tend to indicate that the term spread may dominate the short-term rate as a predictive source for future growth. Contrary to this result, however, Bernanke and Blinder (1992) found that the Federal funds rate was the dominant variable, among other rates and money measures, in predicting economic activity. Smets and Tsatsaronis (1997), using a SVAR interpretation of the different types of shocks, conclude that inflation expectation shocks in long-term interest rate do not have an important real impact in Germany, while it cannot be neglected in the United States.

3.2 Cholesky decomposition of the forecast error variance

To investigate further the importance of the different shocks, and to distinguish endogenous from exogenous interest rate fluctuations, we estimate a VAR system for growth, inflation, short and long-term interest rates. A simple Cholesky decomposition of the error structure, where interest rates rank last, give a first indication of the importance of "pure" exogenous interest rate shocks in the total explanation of the growth and inflation process.

Consider the four-variable VAR system written in autoregressive form:

$B(L)\ x_t = e_t$ with covariance matrix Σ_e.

The Cholesky factorisation decomposes the covariance matrix in terms of a lower triangular matrix θ_o: $\Sigma_e = \theta_o * \theta_o'$. The reduced form errors e_t can then be rewritten in terms of four orthogonal innovations u_t with $e_t = \theta_o u_t$.

The Cholesky decomposition of the covariance matrix implies that the errors of the reduced-form process are restructured into four independent shocks. By setting GDP first in the equation order, the error term in the GDP equation is the first independent real shock, that affects the variables coming behind in a specific order (first inflation, then interest rates). The remaining error in the inflation process is the second independent shock process. By setting interest rates last, we actually deduct from the reduced-form errors, the information already present in the macro-economic variables. This corrects for simultaneity in the error shocks of the different variables and allows us to simulate exogenous shocks in the rates of interest, i.e. interest rate shocks that are independent of those affecting growth and inflation. This further allows a separation of the normal endogenous reaction of interest rates, either through the reaction function of the central bank or through the reaction of private agents to macro-economic disturbances, from pure exogenous shocks in monetary policy or in the long-term yield. The first component of the interest rate process results from the operation of non-monetary shocks, while only the remaining disturbances are considered as of a specific monetary nature. In this respect it, can be noted that the responses of the variable ranking last are independent of the ranking of the preceding variables. We set the long-term interest rate in the last row of the VAR system, behind the short rate, as it is more likely that the short rate does not react contemporaneously to long-rate innovations than vice versa.

Table 8 gives the contribution of each of the four shocks, identified according to the Cholesky decomposition to the explanations of the four variables under consideration. They result from a four-order VAR system estimated on quarterly data for Belgium over the period 1972:1 to 1997:1. The contribution of the two exogenous interest rate innovations to GDP-growth and inflation is very limited. For Belgium, the two interest rate shocks explain no more than 5% of the variability of growth and inflation. For Germany we estimated a similar four-order VAR system over the period 1970:1 to 1997:1 and found the contribution of the short rate to real growth rate fluctuations to be somewhat higher (around 10%). The contribution of both interest rate shocks does not exceed 15% for growth and even less for inflation.

Table 8

Forecast error variance decomposition: Cholesky decomposition

Order of the variables: GDP growth, inflation, short rate, long rate

Belgium								
Quarters	**GDP growth**				**Short rate**			
	Output	Inflation	Short rate	Long rate	Output	Inflation	Short rate	Long rate
0	1.00	0.00	0.00	0.00	0.13	0.02	0.84	0.00
4	0.90	0.07	0.03	0.01	0.14	0.23	0.62	0.01
8	0.89	0.07	0.03	0.01	0.13	0.25	0.58	0.04
12	0.89	0.07	0.03	0.01	0.11	0.28	0.56	0.05
16	0.89	0.07	0.03	0.01	0.11	0.29	0.54	0.06
20	0.89	0.07	0.03	0.01	0.10	0.30	0.53	0.06
24	0.89	0.07	0.03	0.01	0.10	0.31	0.53	0.06
	Inflation				**Long rate**			
	Output	Inflation	Short rate	Long rate	Output	Inflation	Short rate	Long rate
0	0.00	1.00	0.00	0.00	0.00	0.01	0.17	0.82
4	0.05	0.91	0.02	0.03	0.02	0.13	0.17	0.68
8	0.05	0.90	0.03	0.03	0.05	0.27	0.20	0.47
12	0.05	0.90	0.03	0.03	0.05	0.32	0.24	0.39
16	0.05	0.89	0.03	0.03	0.05	0.33	0.26	0.36
20	0.05	0.89	0.03	0.03	0.05	0.34	0.27	0.34
24	0.05	0.89	0.03	0.03	0.05	0.34	0.28	0.33
Germany								
Quarters	**GDP growth**				**Short rate**			
	Output	Inflation	Short rate	Long rate	Output	Inflation	Short rate	Long rate
0	1.00	0.00	0.00	0.00	0.00	0.08	0.92	0.00
4	0.81	0.09	0.07	0.03	0.07	0.13	0.79	0.01
8	0.78	0.10	0.09	0.04	0.14	0.21	0.63	0.01
12	0.77	0.11	0.09	0.04	0.14	0.22	0.60	0.03
16	0.76	0.11	0.09	0.04	0.14	0.22	0.59	0.06
20	0.76	0.11	0.09	0.04	0.14	0.22	0.58	0.06
24	0.76	0.11	0.10	0.04	0.14	0.23	0.58	0.06
	Inflation				**Long rate**			
	Output	Inflation	Short rate	Long rate	Output	Inflation	Short rate	Long rate
0	0.00	1.00	0.00	0.00	0.13	0.05	0.19	0.64
4	0.05	0.85	0.04	0.06	0.15	0.23	0.17	0.45
8	0.06	0.84	0.05	0.05	0.14	0.40	0.12	0.34
12	0.06	0.83	0.06	0.05	0.12	0.45	0.13	0.30
16	0.06	0.82	0.06	0.05	0.12	0.45	0.14	0.29
20	0.07	0.82	0.06	0.05	0.12	0.45	0.14	0.29
24	0.07	0.82	0.06	0.05	0.12	0.45	0.14	0.28

These results may, however, underestimate the importance of interest rate shocks since the application of the Cholesky decomposition method implies independence of the inflation process from monetary policy innovations (the implied independence of the GDP growth process from short-term interest rate innovations is in this respect less restrictive as it is normally assumed that monetary policy does not affect growth immediately). To get a more meaningful interpretation of the different shocks it is necessary to use a structural approach that allows the imposition of theoretical restrictions to identify the independent structural innovations that drive the joint VAR system.

3.3 A structural-VAR approach

We will not discuss the underlying theoretical model in detail here but limit ourselves to a short discussion of the theoretical restrictions that are actually used. For a discussion of the theoretical model we refer to Fuhrer and Moore (1995), and Smets and Tsatsaronis (1997). Following the literature on Structural VAR models, we distinguish supply, demand, monetary policy and long term interest rate shocks by the following assumptions:

- only supply shocks have long run real effects. This assumption follows from a theoretical model with a vertical long-run supply curve. It implies three zero-restrictions on the long-term impact of the three remaining shocks on GDP growth. A positive supply shock (for instance, a productivity increase or a real wage decrease) should have a negative impact effect on inflation and, depending on the reaction function of the monetary authorities, on the short term interest rate;
- demand shocks can influence all four variables on impact: an increase in demand in a model with price rigidity affects both real GDP and inflation positively. Again depending on the reaction function of the monetary authorities, the short interest rate will increase and, depending on the persistence of the short rate increase, the long rate will follow. In the long run, demand shocks should be neutral for output;
- monetary policy does not affect real growth contemporaneously: this is a restriction on the short-term impact. A restrictive monetary policy should be reflected in a higher short-term and long-term interest rate, with probably a negative impact effect on inflation. Long-run neutrality of monetary policy on output is a generally accepted restriction;
- the fourth type of shock can be identified as an innovation in the risk premium or inflationary expectations that drive the long-term interest rate. This shock is identified by two short-term restrictions: it should not influence contemporaneously real growth and monetary policy actions as measured by the short-term interest rate. On the contrary an increase in the long-term interest rate, may be accompanied by an increase in inflation as far as it reflects an "inflation scare" effect that is subsequently realised or self-fulfilling.

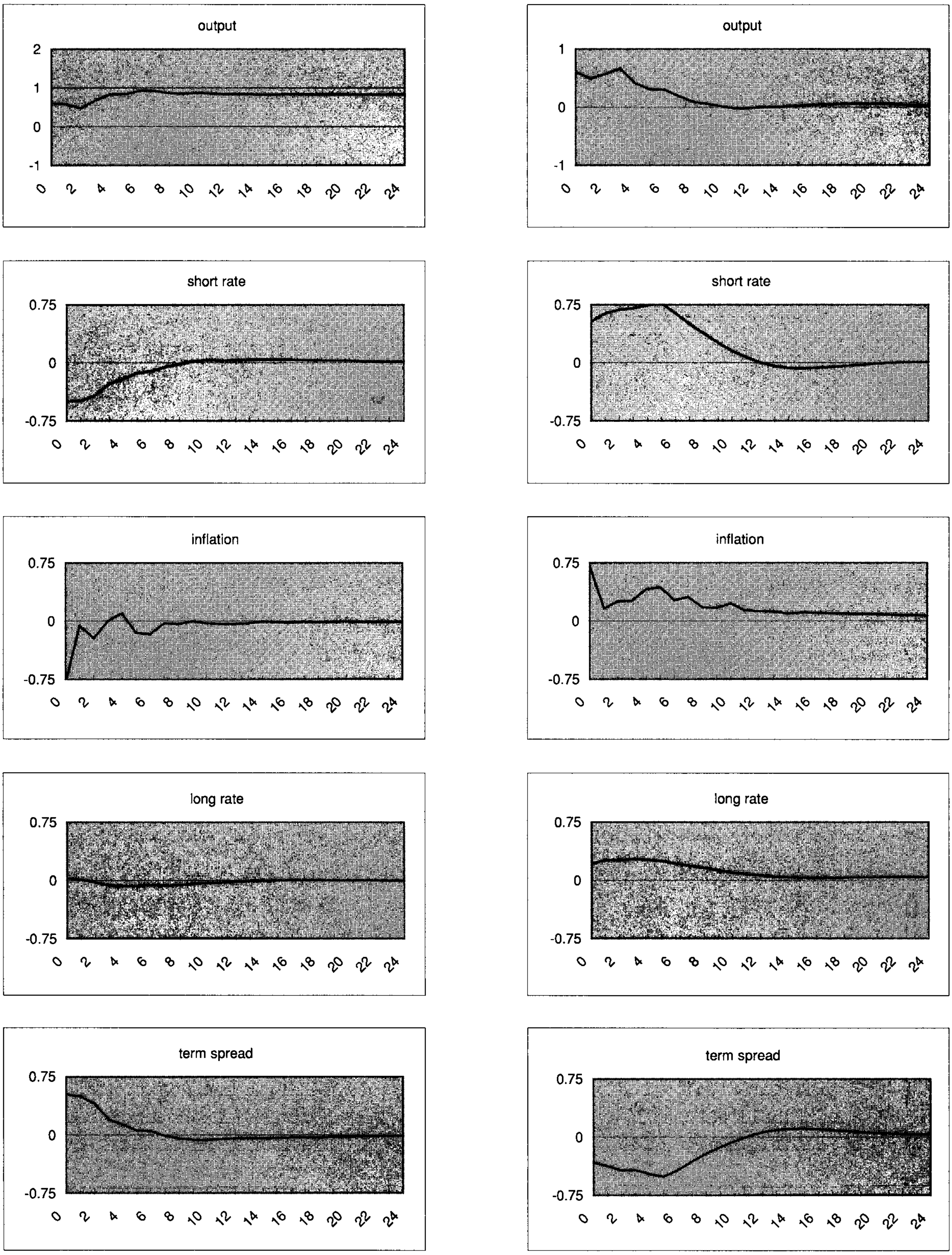
These theoretical considerations provide six restrictions on the parameters of the decomposition matrix θ_o: three short-term restrictions directly on the elements of θ_o, and three long-term restrictions on $\theta(1)$ with $\theta(1) = C(1)*\theta_o$ and $C(1)$ the sum of the vector moving average coefficients of the model $x_t = B(L)^{-1} * e_t = C(L) * e_t$. So, together with the ten restrictions on θ_o, resulting from the symmetry of the covariance matrix, the identification of the model is complete.

This structural model, applied to the VAR system for the German data, produces expected results. The impact of the different shocks is shown in the impulse responses of the four types of shocks, and these correspond to the theoretical expectations (Graph 2). Using the theoretical restrictions to identify the monetary policy shock and the shocks in the long-term interest rate, the contribution of the interest rate shocks in the variance decomposition of inflation is strongly increased (Table 9). According to our estimation results, the autonomous shocks in monetary policy explain about 40% of the variability of inflation and the contribution of the long-term interest rate shocks is increased towards 20%. The contribution to real growth fluctuations remains limited to a joint 12%. These results are close to the ones obtained by Smets and Tsatsaronis (1996), although our long-term interest rate effect is somewhat stronger.

Graph 2a

Impulse response of the SVAR for Germany
Quarterly basis

Suppy shock | Demand shock



Graph 2b

Impulse response of the SVAR for Germany

Quarterly basis

Monetary policy shock | Long interest rate shock

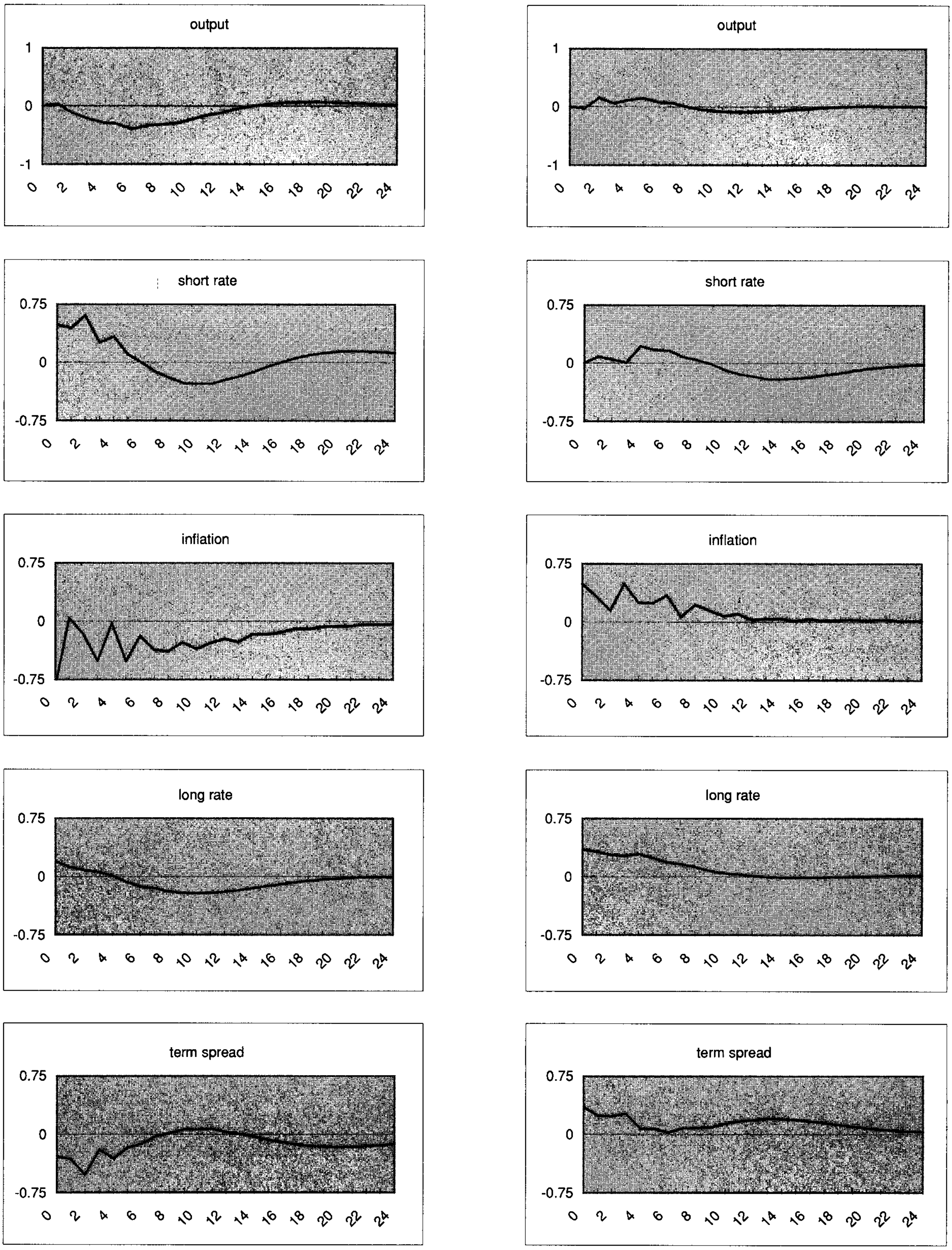


Table 9

Forecast error variance decomposition: SVAR model

	Belgium							
Quarters	**GDP growth**				**Short rate**			
	Supply	Demand	Mon. pol.	Long rate	Supply	Demand	Mon. pol.	Long rate
0	0.72	0.28	0.00	0.00	0.01	0.28	0.71	0.00
4	0.61	0.33	0.05	0.01	0.06	0.47	0.46	0.01
8	0.61	0.33	0.05	0.01	0.06	0.48	0.42	0.04
12	0.61	0.33	0.05	0.01	0.06	0.49	0.39	0.06
16	0.61	0.33	0.05	0.01	0.06	0.50	0.37	0.07
20	0.61	0.33	0.05	0.01	0.06	0.51	0.36	0.07
24	0.61	0.33	0.05	0.01	0.06	0.52	0.35	0.07
	Inflation				**Long rate**			
	Supply	Demand	Mon. pol.	Long rate	Supply	Demand	Mon. pol.	Long rate
0	0.26	0.67	0.07	0.00	0.01	0.02	0.15	0.82
4	0.22	0.67	0.09	0.02	0.02	0.17	0.11	0.70
8	0.23	0.66	0.09	0.03	0.02	0.38	0.10	0.49
12	0.22	0.66	0.09	0.03	0.03	0.44	0.12	0.41
16	0.22	0.66	0.09	0.03	0.04	0.46	0.13	0.38
20	0.22	0.66	0.09	0.03	0.04	0.47	0.13	0.36
24	0.22	0.66	0.09	0.03	0.04	0.48	0.14	0.35
	Germany							
Quarters	**GDP growth**				**Short rate**			
	Supply	Demand	Mon. pol.	Long rate	Supply	Demand	Mon. pol.	Long rate
0	0.49	0.51	0.00	0.00	0.32	0.37	0.30	0.00
4	0.44	0.47	0.04	0.05	0.20	0.55	0.24	0.01
8	0.42	0.47	0.05	0.06	0.15	0.64	0.19	0.02
12	0.42	0.47	0.06	0.06	0.14	0.61	0.22	0.03
16	0.41	0.46	0.07	0.06	0.13	0.59	0.22	0.05
20	0.41	0.46	0.07	0.06	0.13	0.58	0.22	0.06
24	0.41	0.46	0.07	0.06	0.13	0.58	0.23	0.06
	Inflation				**Long rate**			
	Supply	Demand	Mon. pol.	Long rate	Supply	Demand	Mon. pol.	Long rate
0	0.30	0.24	0.34	0.11	0.00	0.21	0.19	0.60
4	0.22	0.26	0.32	0.21	0.01	0.37	0.08	0.54
8	0.17	0.27	0.36	0.20	0.02	0.39	0.11	0.48
12	0.15	0.27	0.39	0.19	0.02	0.35	0.21	0.41
16	0.15	0.26	0.41	0.18	0.02	0.34	0.25	0.39
20	0.15	0.27	0.41	0.18	0.02	0.34	0.25	0.39
24	0.15	0.27	0.41	0.18	0.02	0.34	0.25	0.38

When applying the model to Belgium, we introduce the German data (contemporaneously and one lag) into the equations as representatives of exogenous foreign shocks. These exogenous variables explain already a large part of both macro-economic variables and interest rates. What is left are domestic shocks, which can be identified with the same combination of short and long-term restrictions as those mentioned above. The results, summarised in the impulse responses in Graph 3, are again acceptable:

- the supply shock has a positive effect on growth and a negative one on inflation. Both interest rates decline only gradually but very persistently. The strong negative impact effect on the short-term interest rate, as found in Germany, cannot be expected in Belgium where monetary policy is fully concentrated on the exchange rate objective;
- the demand shock has a strong positive impact on both real growth, inflation and interest rates. Here, the impact effect on the short-term interest rate is acceptable as a positive demand shock, probably originating in public expenditures and causing a worsening of the current account. This is likely to have a direct impact on the exchange rate and therefore, given the objective of monetary policy, on the short-term interest rate;
- monetary policy shocks, reflected in a strong short-term interest rate increase, only have a small negative impact effect on inflation and are followed by a moderate increase in the long rate. The small effect on inflation is acceptable as the short-term interest rate in Belgium is mainly increased to offset exchange rate pressure. As this policy had to gain credibility during the estimation period, the small positive long-term effect on inflation can be considered as acceptable;
- the long-term interest rate effect is not followed by a similar movement in inflation but is rather reflected in the short-term interest rate. This result seems logical given that such shocks in Belgium were more likely related to a decrease in the risk premium on Belgian franc investments, following perceived improvements in the underlying fundamentals (government deficit and current account). A shock in the long-term Belgian franc rate should therefore be considered as a risk premium shock rather than as an innovation in inflation expectations.

From the variance decomposition in Table 9, it follows that the explanatory power of domestic monetary policy and long-term interest rate innovations in the Belgian case, remains very limited as far as real growth and inflation is concerned. However the German interest rates, that enter the equations as exogenous variables, do have a significant impact on real growth and inflation. The contribution of these shocks can, however, only be evaluated if a joint VAR system for the two countries has been estimated.

The decomposition of interest rates, growth and inflation into the four underlying structural shocks that drive the economy, now allows us to look for the reasons of the observed leading character of the term structure with respect to growth and inflation. This information can be obtained from the decomposition of the covariance between growth and inflation with the lagged term structure.

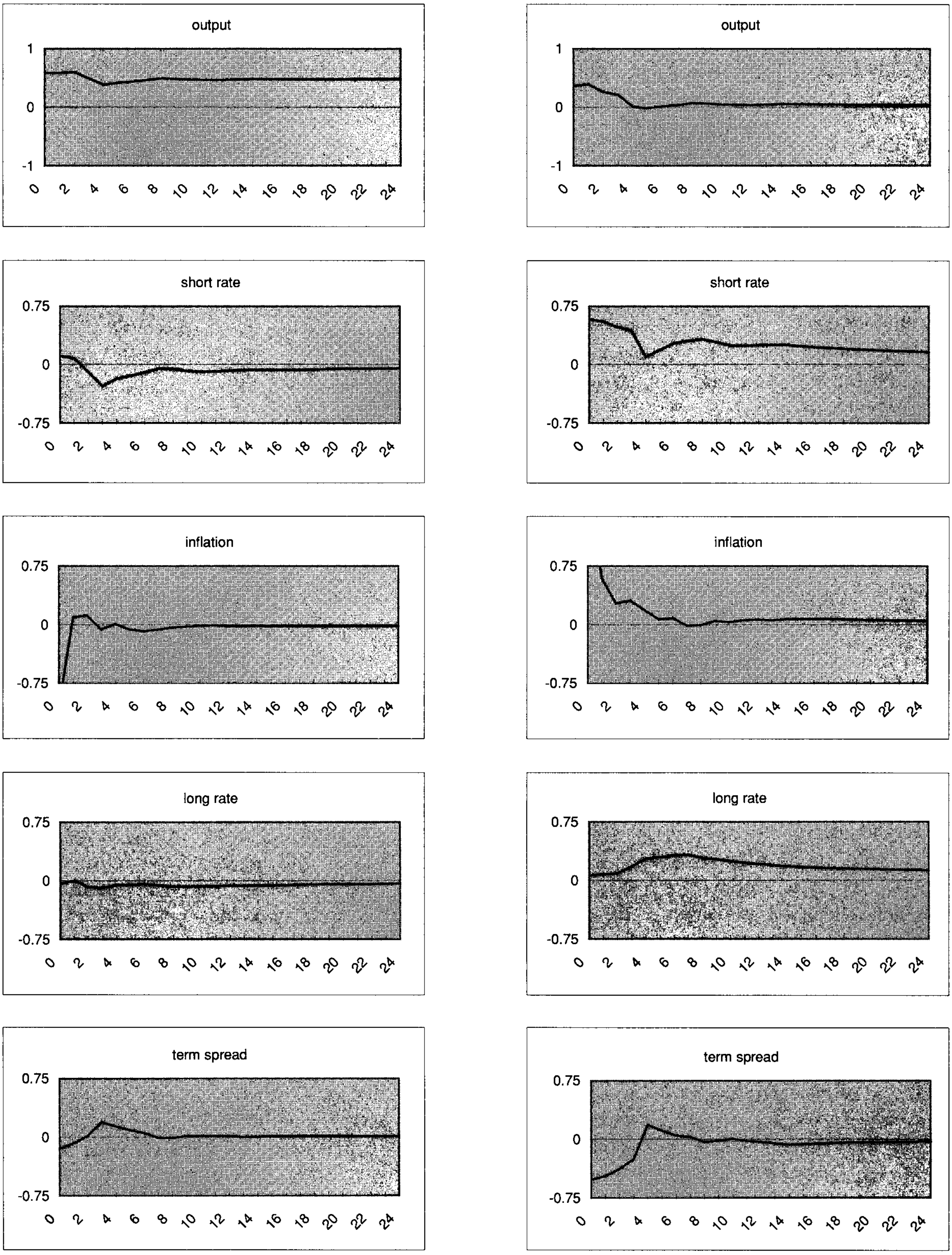
In Germany, the positive covariance between growth and the lagged term structure is mainly explained by supply and demand shocks (Graph 4). But monetary policy shocks also contribute to the positive covariance. By pushing up the short rate and flattening the yield curve, a restrictive policy has a negative effect on growth in the following quarters. The positive correlation between the lagged term spread and growth is especially strong in the short run, up to one year. This result corresponds to the expectations tests in Section 2.2 where the predictive content of the term structure, as far as growth was concerned, was mainly found in the short end of the maturity structure.

A similar analysis decomposing the covariance between the lagged term spread and the rate of inflation is presented in Graph 4. The covariance is close to zero up to one year and becomes slightly positive only for longer lags. This net result is obtained as a sum of significant individual contributions that tend to work in opposite directions. On the one hand, supply and especially demand shocks suggest a strong negative correlation: a demand shock has a positive effect on inflation but is followed by a strong decrease in the term spread as monetary policy reacts restrictively such that the term spread tends to be negatively correlated with current and future inflation. On the other hand, monetary shocks and innovations in inflationary expectations or in the risk premium induce positive correlation between the term spread and future inflation. At longer lags these positive contributions tend to dominate the negative ones induced by demand and supply shocks. The results provide an explanation for the conclusion reached in many tests of the information content of the term structure

Graph 3a

Impulse response of the SVAR for Belgium
Quarterly basis

Suppy shock | Demand shock

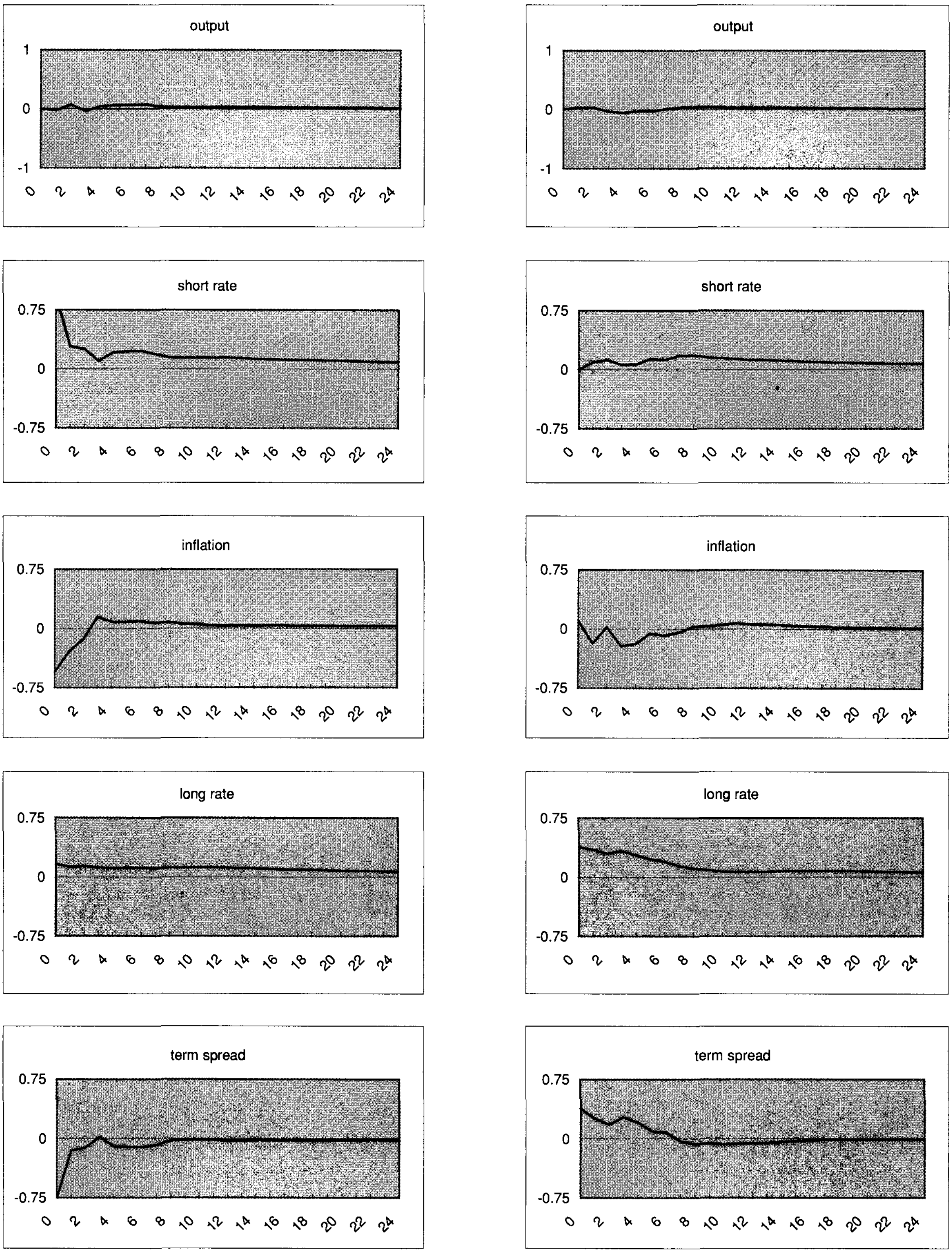


Graph 3b

Impulse response of the SVAR for Belgium

Quarterly basis

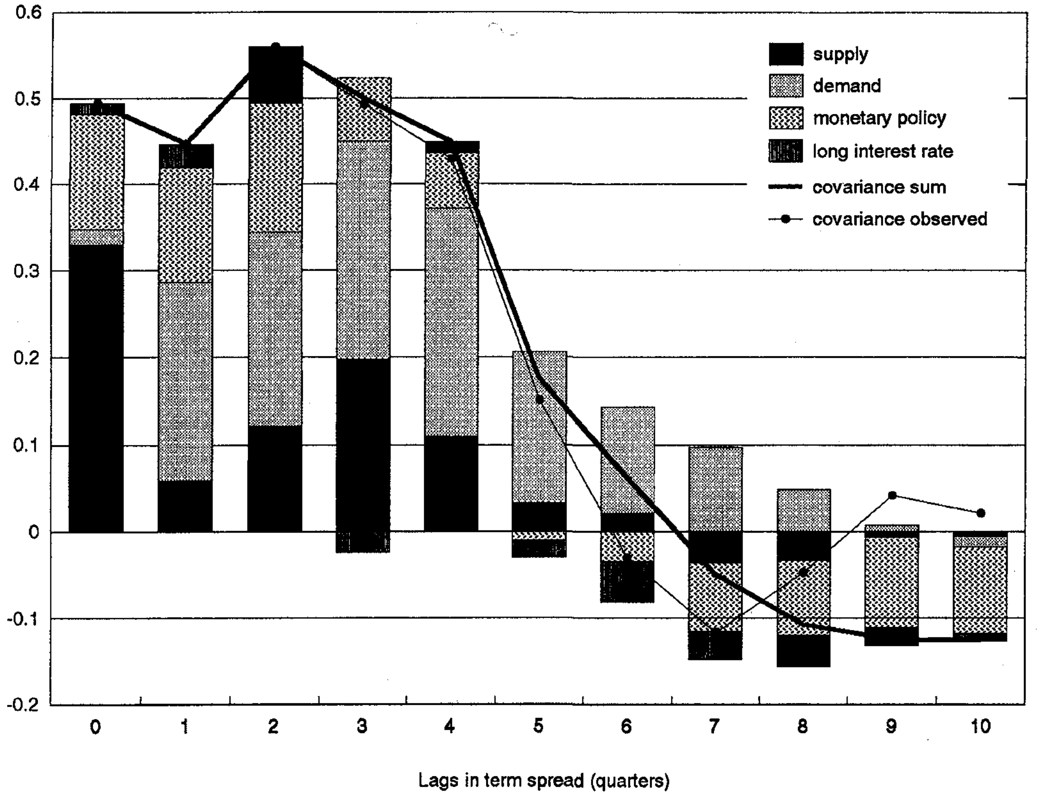
Monetary policy shock | Long interest rate shock



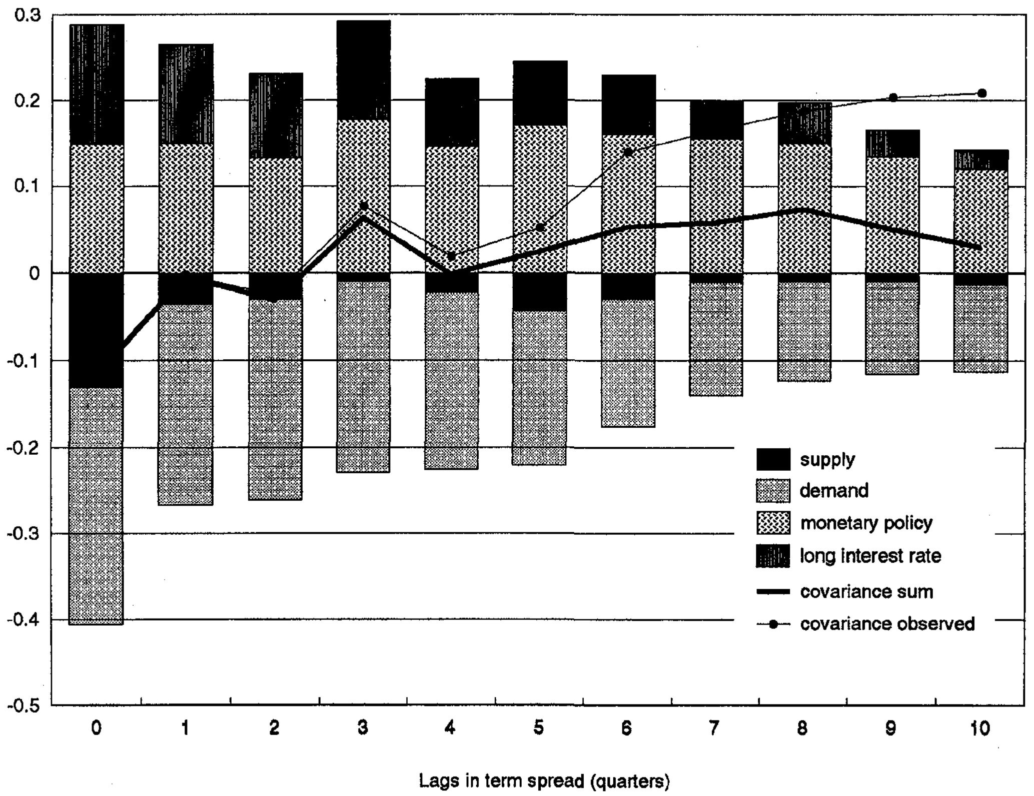
Graph 4

Structural decomposition of growth and inflation/term spread covariance in Germany

Growth



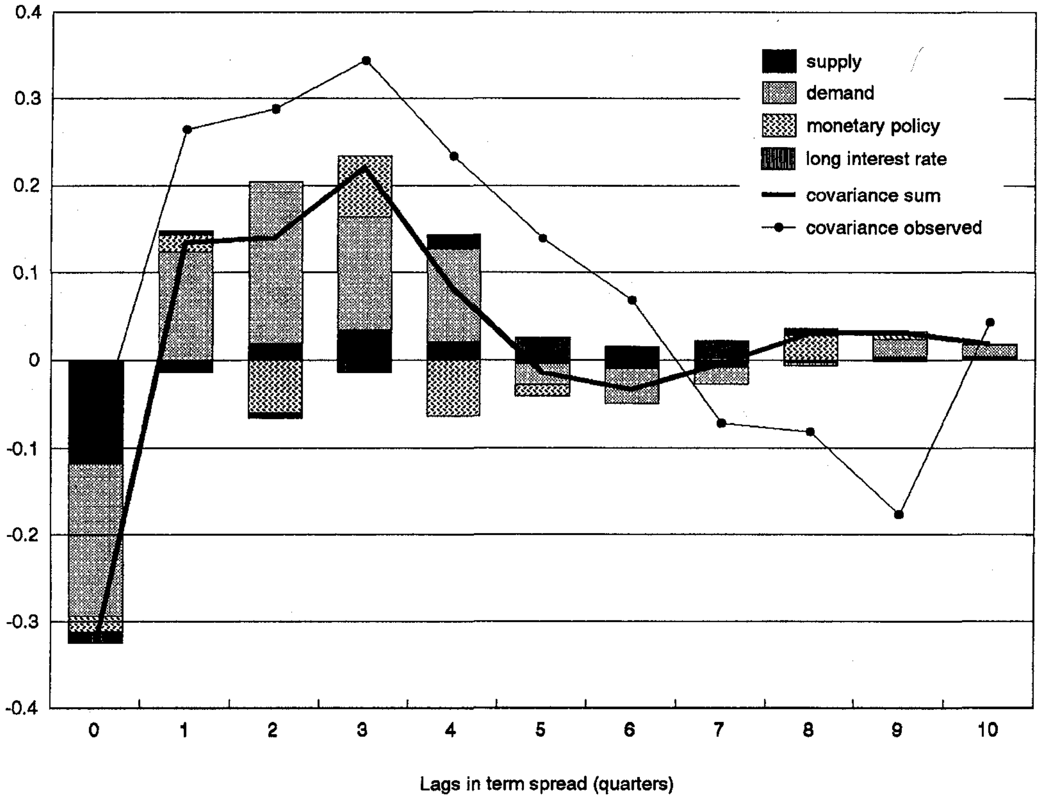
Inflation



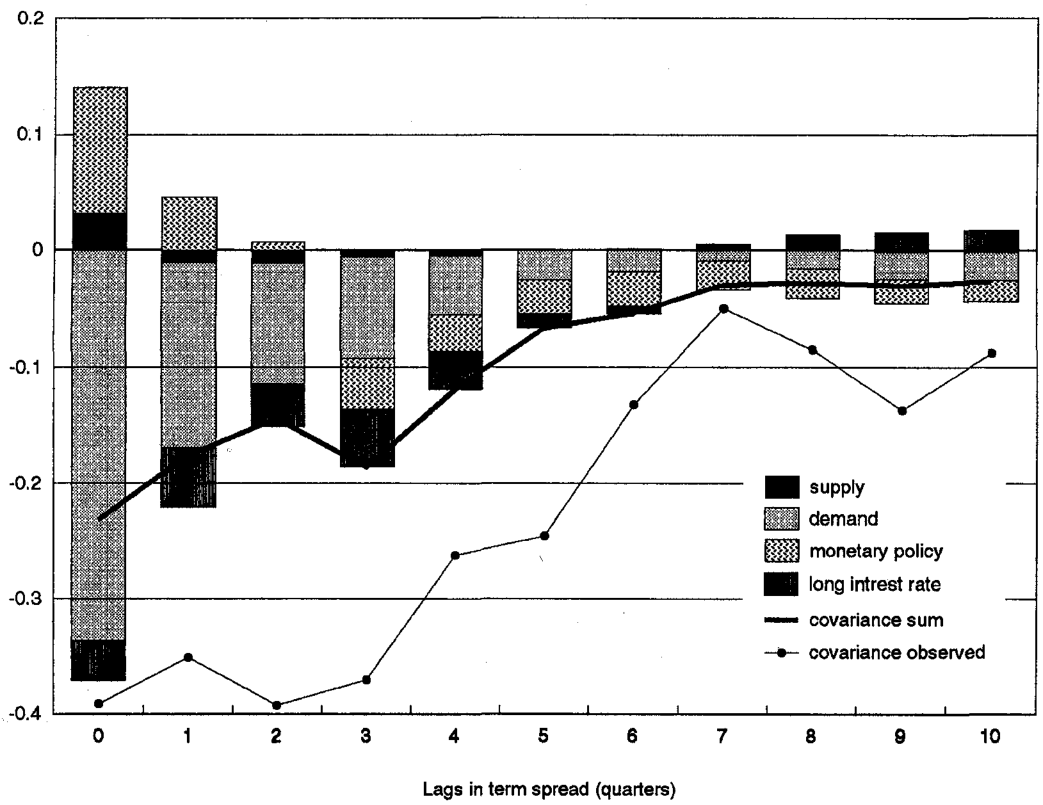
Graph 5

Structural decomposition of growth and inflation/term spread covariance in Belgium

Growth



Inflation



according to which the term spread is a predictor of future inflation at longer time horizons only (see also Section 2.1). Graph 4 also indicates that our VAR model is not able to fully reproduce the observed positive covariances between inflation and the term structure especially at longer lags. An insufficient number of lags in the estimated VAR model is the main reason for this imperfection.

Applying the same exercise to Belgian data (Graph 5) gives rise to several observations. The exogenous German variables in the model provide a strong contribution to the explanation of the observed covariances (this is demonstrated by the significant deviation between the observed and explained values of the covariances). As far as the domestic shocks are concerned, only demand surprises contribute significantly to the covariances (positive and negative contributions to the covariance between the term spread and, respectively, growth and inflation). As explained above, neither domestic monetary policy shocks nor the unexpected movements in the risk premium present in the long-term rate interest rate are able to offset the contribution of demand shocks to the observed negative correlation between the term spread and future inflation in Belgium.

In general, the results of this SVAR exercise correspond with previous tests for Belgium, indicating that domestic interest rate shocks are less important in explaining the correlation between the term spread and future growth and inflation rates, because these comovements tend to be caused mainly by shocks originating in Germany.

When applying these kinds of models to monetary policy analysis, it should be remembered that their results only provide average outcomes conditioned by the sample period. Specific questions related to actual monetary policy issues or to the interpretation of the actual slope of the yield curve, need to based on a careful analysis of the actual economic situation in terms of the shocks discussed in this paper.

Conclusions

Traditional tests of the information content of the term structure of interest rates reveal that the slope of the yield curve is correlated with future changes in inflation and with future real growth. It was therefore concluded that the yield curve's inclination contains information on market participants' expectations concerning the future course of inflation and growth. On the other hand, evidence has also emerged indicating that the slope of the yield curve may be significantly affected by actual or by market perceived changes in official central banks' interest rates. The joint events whereby the term spread reflects market participants' expectations about inflation and that, at the same time, the term spread is itself affected by central banks' reactions, may imply policy instability whenever the central bank effectively tries to use the term spread as an indicator of future inflation in setting its official interest rates. It is therefore important to analyse the relative importance of the contribution of monetary policy shocks as compared to other types of innovations that may affect the slope of the yield curve. If monetary shocks were found to be dominant, then the term spread would mainly reflect the stance of monetary policy.

Granger causality tests indicate that short-term interest rates have a much stronger predictive impact on future inflation and growth as compared to long rates, suggesting that the observed positive correlations between the term spread and future output growth and inflation is mainly due to monetary policy reactions. For example, a rise in the official interest rate, as a reaction to unfavourable inflation signals, lifts the short end of the yield curve. Its impact on the long end of the term structure may be relatively minor in so far as inflation shocks are perceived as persistent but essentially temporary in nature. Market participants therefore expect the short rate to come back to a "normal" level in the long run in line with the central bank's inflation target, such that long-term interest rates are hardly affected by a temporary rise in short-term interest rates.

Other evidence can be found from a structural vector autoregression model. Such a VAR system in inflation, growth, short and long-term interest rates was used to identify supply, demand, monetary policy and long-term interest rate shocks. We decomposed the observed positive covariance between the slope of the term structure and future inflation and found that, especially at the longer end of the yield curve, unexpected shocks in short-term interest rates explain a large part of the observed positive covariance. Innovations in the long-term interest rate, e.g. due to new inflation signals, only explain a minor part of this covariance.

These results imply that prudence is required when using the slope of the yield curve as an indicator of (forward looking) monetary policy formulation. Changes in the shape of the yield curve may signal different types of unexpected events in both the real and financial sectors of the economy. Those changes should therefore first be carefully interpreted in terms of underlying structural shocks in order to identify the information which such changes are actually signalling.

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