# Loan supply shocks and the business cycle

Luca Gambetti*
Universitat Autonoma de Barcelona

Alberto Musso†
ECB

January 24, 2012

**Abstract**

This paper provide empirical evidence on the role played by loan supply shocks over the business cycle in the Euro Area, the United Kingdom and the United States from 1980 to 2010 by applying a time-varying parameters VAR model with stochastic volatility and identifying these shocks with sign restrictions. The evidence suggests that loan supply shocks appear to have a significant effect on economic activity and credit market variables, but to some extent also inflation, in all three economic areas. Moreover, we report evidence that the short term impact of these shocks on real GDP and loan volumes appears to have increased in all three economic areas over the past few years. The results of the analysis also suggest that the impact of loan supply shocks seems to be particularly important during slowdowns in economic activity. As regards the most recent recession, we find that the contribution of these shocks can explain about one half of the decline in annual real GDP growth during 2008 and 2009 in the Euro Area and the United States and possibly about three fourths of that observed in the United Kingdom. Finally, the contribution of loan supply shocks to the decline in the annual growth rate of loans observed from the peaks of 2007 to the troughs of 2009/2010 was slightly less than half of the total decline in the Euro Area and the United States and somewhat more than half of that in the United Kingdom.

JEL classification: C32; E32; E51.

Keywords: Loan supply; Business cycle; Euro Area; UK; US; time-varying VAR; sign retrictions.

---

*The financial support from the Spanish Ministry of Science and Innovation through grant ECO2009-09847 and the Barcelona Graduate School Research Network is gratefully acknowledged. Contact: Office B3.1130 Departament d'Economia i Historia Economica, Edifici B, Universitat Autonoma de Barcelona, Bellaterra 08193, Barcelona, Spain. Tel (+34) 935814569; e-mail: luca.gambetti@uab.cat

†Contact: ECB, Kaiserstrasse 29, 60311 Frankfurt am Main, Germany. Tel (+49) 6913447076; e-mail:alberto.musso@ecb.europa.eu. The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank.

# 1 Introduction

Financial intermediaries and credit markets more in general appear to have played a significant role in the context of the events which led to the severe recession experienced during 2008 and 2009 by advanced economies such as the Euro Area, the United Kingdom and the United States. Indeed, the economic crisis was preceded and accompanied by financial turbulence in various segments of financial markets, such as the US subprime mortgage market and the international interbank short-term liquidity market. Moreover, Lehman Brothers' default in September 2008 clearly exacerbated the financial and economic crisis, also bringing at the centre of the attention questions regarding the actual state of banks balance sheets and their ability to provide loans to households and non-financial corporations to finance consumption and investment expenditure, among other effects. In addition, it is widely agreed that specific developments in the banking industry, such as the process of securitisation and the increasing recourse to short-term debt, contributed markedly to the lending boom and housing bubble of the mid-2000s and subsequent credit slowdown and house price fall (Brunnermeier, 2009, Diamond and Rajan, 2009, Gorton, 2009).

From a policy perspective it is important to assess the relative role of supply and demand forces in driving credit, output and inflation developments, especially during periods around crises such as the recent one. Indeed, these factors may call for a very different response of monetary and fiscal policy. Clearly, an insufficient provision of loans to the private sector by banks caused by balance sheet constraints affecting financial intermediaries may require a different policy response compared to the case of declining loan growth due to declining demand from households and enterprises. Thus, for a central bank it is essential to know whether loan flows to the private sector decline mainly because of problems affecting balance sheets of banks or largely because the demand for credit is diminishing. In the former case measures to support the banking system may be needed, while in the latter case measures to support to real economy may have priority. Another key challenge which policy-makers face is to disentangle the role of credit markets as propagators of shocks originating in other sectors of the economy (such as technological innovations, unexpected changes in oil prices or investors' changes in confidence, to make few examples relating to both aggregate supply and aggregate demand shocks) and as impulse mechanisms, that it sources of disturbances or shocks. Indeed, the provision of loans to the private sector by banks depends on the state of banks capital and financing capability, which in turn change both (endogenously) due to the economy's changing conditions as well as (exogenously) due to factors directly affecting banks balance sheets. Clearly, the source of the potential problem is different in these two cases.

Against this background, a key challenge for policy-makers is to quantify the contribution of supply shocks to loan growth. The purpose of this paper is to propose a methodology which allows for such contributions to be estimated in the context of an empirical model which takes into account potentially important changes in the macroeconomy and to provide some empirical evidence for the Euro Area, the United Kingdom and the United States. To account for possibly significant changes in the macroeconomic environment is a potentially very important step in deriving reliable estimates of the impact of loan supply shocks as major changes have been taking place in recent years. For example, there is evidence that the volatility of shocks my have changed over time (Cogley and Sargent, 2005, Fernández-Villaverde and Rubio-Ramírez, 2010). Moreover, in addition to the evidence for a Great Moderation starting in the mid-1980s to the early 1990s, depending on the countries considered, the recent economic and financial crisis may have induced a further gradual structural change in the economy, for example affecting persistently economic agents' risk aversion, and although it may be too early to conclude to which extent fundamental underlying changes may have taken place it is important to allow for them. Thus, it is critical to estimate the impact of loan supply shocks in a framework which allows for possible changes in stochastic volatility and time-varying parameters. The model we use, a time-varying parameter VAR with stochastic volatility, seems particularly suited for the purpose of this paper. This is one of the main advantages of the approach adopted in this study compared to the literature which has attempted to estimate the effects of loan supply shocks, which typically is based on fixed parameters and constant volatility models (Lown and Morgan, 2006; Bassett et al., 2010; Busch et al., 2010; Ciccarelli et al., 2010; De Nicolò and Lucchetta, 2011; Gilchrist and Zakrajšek, 2011; Hristov et al., 2011). The identification of loan supply shocks we adopt is based on sign restrictions. The latter have been applied before to identify these shocks (see for example Musso, 2009; Busch et al., 2010; De Nicoló and Lucchetta, 2011; Hristov et al., 2011) but we argue that the way they have been specified has in most cases limitations which we try to overcome, as we will argue below. Moreover, our paper is the first to provide a systematic comparison across the Euro Area, the United Kingdom and the United States.

The main results of the empirical analysis are the following. First, loan supply shocks appear to have a significant effect on economic activity and credit markets, but to some extent also inflation, in all three economic areas. However, some differences across geographic areas can also be uncovered. For example, the short term impact on real GDP and loan volumes appears to be stronger in the United States and, especially for loan growth, in the United Kingdom, than in the Euro Area. Second, the impact of these shocks may have changed over time, as for example the short term impact of these shocks on real GDP and loans seems to have increased in all three economic areas over the past few years. Third, it appears that the contribution of loan supply shocks is particulary important during slowdowns. For example, the contribution of these shocks can explain about one half of the decline in annual real GDP growth during 2008 and 2009 in the Euro Area and the United States and possibly about three fourths of that observed in the United Kingdom. Finally, the contribution of loan supply shocks to the decline in the annual growth rate of loans observed from the peaks of 2007 to the troughs of 2009/2010 was slightly less than half of the total decline in the Euro Area and the United States and somewhat more than half of that in the United Kingdom.

The remaining of the paper is structured as follows. Section 2 illustrates the empirical approach and describes the data. Section 3 reports and discusses the results. Section 4 provides conclusions.

## 2 The empirical approach

In this section we describe the econometric model used as well as the data for the three economic areas considered.

### 2.1 The model

We carry out the analysis using a time-varying VAR model with stochastic volatility. The model has become a quite popular tool in macroeconomics, over the last few years, to address questions related to the evolution of the structure of the economy and the volatility of the shocks (see Cogley and Sargent, 2005, Primiceri, 2005, Benati, 2008, Canova and Gambetti, 2009, Gali and Gambetti, 2009). Moreover D'Agostino, Gambetti and Giannone (2011) shows that the model has a good forecasting performance.

Let $y_t$ be a vector containing the variables of interest (real GDP, consumer prices, loan volumes, a composite lending rate and a reference short term interest rate) and assume it satisfies

$$y_t = A_{0,t} + A_{1,t}y_{t-1} + ... + A_{p,t}y_{t-p} + \varepsilon_t \tag{1}$$

where $A_{0,t}$ is a vector of time-varying intercepts, $A_{i,t}$ are matrices of time-varying coefficients, $i = 1, ..., p$ and $\varepsilon_t$ is a Gaussian white noise with zero mean and time-varying covariance matrix $\Sigma_t$. Let $A_t = [A_{0,t}, A_{1,t}..., A_{p,t}]$, and $\theta_t = vec(A_t')$, where $vec(\cdot)$ is the column stacking operator. Conditional on such an assumption, we postulate the following law of motion for $\theta_t$:

$$\theta_t = \theta_{t-1} + \omega_t \tag{2}$$

where $\omega_t$ is a Gaussian white noise with zero mean and covariance $\Omega$. We let $\Sigma_t = F_t D_t F_t'$, where $F_t$ is lower triangular, with ones on the main diagonal, and $D_t$ a diagonal matrix. Let $\sigma_t$ be the vector of the diagonal elements of $D_t^{1/2}$ and $\phi_{i,t}$, $i = 1, ..., n-1$ the column vector formed by the non-zero and non-one elements of the $(i+1)$-th row of $F_t^{-1}$. We assume that

$$\log \sigma_t = \log \sigma_{t-1} + \xi_t \quad (3)$$

$$\phi_{i,t} = \phi_{i,t-1} + \psi_{i,t} \quad (4)$$

where $\xi_t$ and $\psi_{i,t}$ are Gaussian white noises with zero mean and covariance matrix $\Xi$ and $\Psi_i$, respectively. Let $\phi_t = [\phi'_{1,t}, \ldots, \phi'_{n-1,t}]$, $\psi_t = [\psi'_{1,t}, \ldots, \psi'_{n-1,t}]$, and $\Psi$ be the covariance matrix of $\psi_t$. We assume that $\psi_{i,t}$ is independent of $\psi_{j,t}$, for $j \neq i$, and that $\xi_t$, $\psi_t$, $\omega_t$, $\varepsilon_t$ are mutually uncorrelated at all leads and lags. Details about the estimation can be found in Appendix A.

The impulse response functions in this model are derived from the approximated MA representation

$$y_t = \mu_t + C_t(L)\varepsilon_t \quad (5)$$

where $C_t(L) = \sum_{k=1}^{\infty} C_{k,t}L^k$, $C_{0,t} = I$, $\mu_t = \sum_{k=0}^{\infty} C_{k,t}A_{0t}$, $C_{k,t} = \mathcal{S}_{n,n}(\mathbf{A}_t^k)$, $\mathbf{A}_t = \binom{A_t}{I_{n(p-1)} \quad 0_{n(p-1),n}}$ and $\mathcal{S}_{n,n}(X)$ is a function which selects the first $n$ rows and $n$ columns of the matrix $X$.

Structural impulse response functions are derived using the (lower triangular) Cholesky factor $S_t$ of $\Sigma_t$ ($S_tS_t' = \Sigma_t$) and any orthogonal matrix $H_t$ ($H_tH_t' = I$). The class of structural representation is therefore defined as

$$y_t = \mu_t + C_t(L)S_tH_te_t \quad (6)$$

where $e_t = H_t'S_t^{-1}\varepsilon_t$ and $D_t(L) = C_t(L)S_tH_t$ are the impulse response functions to structural shocks.

## 2.2 Data

For each economy we estimate one model including five variables: real GDP, a consumer price index, non-financial private sector loan volumes, a composite lending rate and a reference short term interest rate. Chart 1 shows all time series used in the analysis, while details on the definition, treatment and sources of the data are reported in Appendix B.

The evolution of real GDP growth shows how all three economic areas experienced recessions in similar periods (the early 1980s, the early 1990s and between 2008 and 2009), although with some variation in terms of turning points. Moreover, the data are consistent with the evidence for a Great Moderation from the mid-1980s until the most recent crisis. It is striking how synchronised and of similar magnitude the slowdown in real GDP growth was between 2008 and 2009 across these economic areas.

The consumer price index selected for each economic area is that representing the main reference for the corresponding central bank: the harmonised index of consumer prices (HICP) for the Euro Area, the retail prices index (RPI) for the United Kingdom and the consumer price index (CPI) for the United States. In all three economic areas it is apparent how inflation gradually declined during the 1980s and has been at relatively low and stable levels since the early 1990s, with signs of increased volatility only reappearing over the last few years.

The reference short term interest rates are represented by the 3-month Treasury bill rates for the United Kingdom and the United States, while for the Euro Area we use the 3-month Euribor up to the beginning of the recent crisis. The crisis which started in August 2007 affected interbank money markets significantly with a loss of confidence and associated disruption of unsecured interbank lending market, implying that the corresponding interest rates (Euribor or Eonia) may be of questionable representativeness as reference interest rates. Thus, we use the 3-month Euro Repo rate, for secured interbank lending, from 2007 onwards as a reference short-term interest rate for the Euro Area.

As regards loan volumes, we consider series which correspond to indices for the outstanding amounts of loans granted by financial intermediaries to households and non-financial corporations, corrected for the impact of loan sales and securitisation. The latter correction is important to gauge the amount of loans originated by banks, as in recent years the fraction of loans granted and subsequently securitised and taken off banks' balance sheets has been significant. For the US we use data from the flow of funds statistics, which include not only loans obtained by US households and non-financial corporations by commercial banks, which in contrast to the Euro Area and to some extent also the United Kingdom represent only a small fraction to total loans obtained by these sectors, but also loans from other sources.[1] The data show how the credit cycles in the three economic areas appear to be relatively synchronised.

For the composite lending rates a weighted average of lending rates for loans to households and for loans to non-financial corporations are used, with weights corresponding to the respective loan outstanding amounts. Since no official series exists for any of these economic areas, we have constructed such series using available interest rates and (for the weights) loan data for the various loan categories. These series have some limitations, especially for the 1980s, as they do not cover all types of loans and are based on data not fully harmonised (for example across Euro Area countries, especially for the 1980s and to some extent also 1990s). The constructed series do not display unexplainable movements or excessive volatility and they seem to behave similarly across the three economic areas, but the limited quality of these data represents a source of uncertainty

[1]See for example the evidence reported in the ECB Monthly Bulletin article entitled "The external financing of households and non-financial corporations: a comparison of the euro area and the United States" (April 2009 issue).

for the results of any analysis like the present one.

### 2.3 Identification

We identify three shocks: a loan supply shock, an aggregate supply shock and an aggregate demand shock. Intuitively, a loan supply shock can be associated with various events, such as unexpected changes in bank capital available for loans (for example due to a change in regulatory capital ratio requirements), changes in bank funding (for instance following bank runs or the introduction of credible deposit insurance schemes or changes in the ceiling of the latter), changes in the risk perception of potential borrowers by bank management (for example following changes in key bank managerial positions or innovations in bank monitoring technology) or changes in the degree of competition in the banking sector. Examples of aggregate supply shocks include technology or productivity shocks, oil price shocks and labour supply shocks. Aggregate demand shocks include consumption or preference shocks, investment demand shocks, monetary policy shocks and fiscal policy shocks.

Although the main focus of the paper is on loan supply shocks, identification of aggregate supply and demand disturbances helps the identification of the loan supply shock. Identification is achieved by means of sign restrictions. As conventionally done, it is assumed that aggregate supply shocks move output and prices in the opposite direction, while aggregate demand shocks affect the two variables with a response of the same sign. The three shocks, if expansionary (i.e., if causing an expansion in real GDP growth), increase loan supply (while contractionary shocks will have symmetric effects). However, while expansionary aggregate demand and supply shocks increase the lending rate, loan supply shocks reduce it. The restrictions are summarized in Table 1 and are imposed on the variables only on impact (the sensitivity analysis section provides a discussion of how results change if restrictions are imposed also up to three periods after the shock). No restriction is imposed on the sign of the responses of short term interest rates to any shock.

The idea underlying these restrictions is that, in the case of an expansionary loan supply shock, if a bank decides exogenously to expand the supply of loans to the private sector it would do so by increasing the quantity made available and/or by decreasing the lending rate (or, more likely, both), such that at aggregate level both effects are observed. This would have an expansionary effect on output as households would borrow more and use some of these funds to expand their consumption and enterprises would borrow more and use some of these funds to expand their investments. However, in contrast to other studies (for example, Busch et al. 2010) we leave the effect on inflation unspecified as it is to some extent uncertain. Indeed, while the increased consumption and investment expenditure would imply inflationary pressures, the lower lending rate implies a lower cost to firms which could potentially respond by decreasing prices of their products. Since it is not obvious which effect might prevail, we leave this impact unspecified. Hristov et al. (2011) provide a discussion on how some benchmark DSGE models with a banking sector lead to effects consistent with those imposed here for loan volumes and spreads (or lending rates) and real GDP, while the effect on aggregate prices is ambiguous. As regards aggregate supply and aggregate supply shocks, it is assumed that expansionary shocks of either category would induce an increase in the demand for loans, leading to an increase in loan quantities as well as an increase in the lending rate. Note that the aggregate demand shock includes also loan demand shocks, but we do not differentiate the latter from other aggregate demand shocks as the variables included in the model do not allow for such distinction. The restrictions are imposed on the lending rate and not on the spread between the lending rate and the short term interest rate as changes in the latter as well as loan volumes may also be induced by shocks other than loan supply, including for example wealth shocks (i.e. an expansionary wealth shock may induce an increase in the demand for loans, leading to a possible increase in the lending rate but also inflationary pressures with a possible increase in the policy rate, with an uncertain sign of the spread in the short run.

Technically speaking, at each point in time and for each draw of the reduced form coefficients we draw $H_t$ in such a way that the elements of each row represent the coordinates of a point uniformly distributed over the unit hypersphere and that is orthogonal to the other points defined by the remaining columns, see Rubio-Ramirez, Waggoner and Zha (2009).

# 3 Results

## 3.1 Evidence of time-variation

The evolution of the residuals time-varying variances is shown in Chart 2. In most cases there is evidence of significant time variation in the residual variances, with spikes appearing most often in the most recent years in correspondence to the latest economic and financial crisis. Moreover, for interest rate there are clear signs of a decrease in their volatilty during the first half of the sample. Overall, the evidence supports the use of stochastic volatility specifications for all three models.

Table 2 shows the posterior mean of the trace of $\Omega$ as well as 68% confidence bands and the trace of $\Omega_0$ (i.e. the prior variance-covariance matrix). This is a way to establish whether time-variation in the parameters is a feature of the data, see Cogley and Sargent (2005). In all three cases, it appears to be the case that the trace of $\Omega_0$ is lower than the 16% percentile, pointing to the presence to time-variation in the data, as the sample points towards greater time variation in the parameters than that of the prior selected.

### 3.2 The average effect of loan supply shocks

The average impulse response functions to loan supply shocks over the whole sample period show remarkable similarities across the three economic areas. The posterior mean of the impulse responses and the 68% confidence bands appear in most cases very similar (see Chart 3). For example, an expansionary loan supply shock seems to have a large but short-lasting (less than a year) impact on real GDP in all three cases. However, it appears to be stronger in the short-run for the United Kingdom and United States, than for the Euro Area, although only moderately so. Moreover, for all three economic areas the impact on inflation tends to be negative in the short run but positive in the medium run, suggesting that beyond the very short run the channel operating through the expansion of demand seems to prevail, and persistent. However, in most cases the response of inflation is very close to zero. On average, expansionary loan supply shocks seem to correspond to a larger increase in loan volumes in the United States and especially the United Kingdom compared to the Euro Area, and to a bigger decline in the lending rate in the United Kingdom than in the Euro Area and United States. However, the persistence of the effect of the initial shocks tends to differ across areas, with a longer-lasting effect appearing for both loan volumes and the lending rate in the United Kingdom.

It can be noticed that for the Euro Area and the United States the average short term response of real GDP growth to a loan supply shock appears to be stronger than that of loan growth, which may appear puzzling at first sight. However, a possible explanation of such result can be associated with the possible reaction of firms to such shock: for example, in the presence of an adverse loan supply shock, firms may decide to cut immediately investments, with negative consequences for real GDP growth, while at the same time compensate for the lower availability of new loans by drawing on previously agreed upon credit lines in order for example to maintain their stocks of products and for other short term expenses.

The average importance of loan supply shocks can be assessed on the basis of variance decompositions, shown in Chart 4 for various horizons. Overall, these shocks seem to explain a sizeable fraction of the variance of all variables in all three economic areas, especially beyond the very short horizon of one quarter. In all three areas, these shocks appear to explain about one fifth of the variance of both real GDP growth and inflation. Loan supply shocks seem to explain a larger fraction of the variance of loan volumes in all three cases, ranging between 20% and 30% beyond very short horizons. Loan supply shocks appear to be less important to explain the variance of interest rates (both the lending rate and the short term interest rate), explaining between 10% and 20% on average.

### 3.3 The evolution of the effect of loan supply shocks over time

The evolution of the impulse responses over time for different horizons suggests that some time variation can be detected in several cases (see Charts 5 to 9, as well as Appendix C). In general, it appears that the short term impact of these shocks on real GDP and loans may have increased in all three economic areas over the past few years (see Charts 5 and 7). For loan growth, also the medium-run (i.e. one to three year) impact of loan supply shocks seems to have increased in the most recent years (see Chart 7). For inflation, the response to loan supply shocks appears to be most often close to zero (Chart 6). Finally, the responses of the lending rate and the short term interest rate appear to have remaind close to zero beyond the short term in all three areas over the whole period, with at most signs of a slightly stronger response of the lending rate in the initial part of the sample in all three economic areas (see Chart 8).

Observing variance decompositions over time also provides some impression of time variation in some cases (see Chart 10 and Appendix D). More specifically, the fraction of real GDP growth variance explained by loan supply shocks appears to have increased in the Euro Area since the mid-1990s and in the United States since the early 2000s. Similar evidence can be detected for the lending rate. By contrast, for inflation, loan growth and short term interest rates no major signs of time variation can be detected in all three economic areas.

The evolution of the effect of loan supply shocks can also be assessed on the basis of historical decompositions, or counterfactuals (which indicate how each variable would have evolved in the absence of these shocks). Overall, it appears that the contribution of loan supply shocks is particulary important during slowdowns (see Chart 11). For example, the contribution of these shocks can explain about one half of the decline in annual real GDP growth during 2008 and 2009 in the Euro Area and the United States and possibly about three fourths of that observed in the United Kingdom. Similarly, in all three economic areas loan supply shocks appear to have contributed to a large extent to the recessions of the early 1990s. Loan supply shocks accounted also for significant fractions in the evolution of loan volumes in all three economies over the whole sample period. In particular, in the absence of loan supply shocks the decline in the annual growth rate of loans observed from the peaks of 2007 to the troughs of 2009/2010 would have been about 30%, 40% and 60% smaller in the United States, Euro Area and United Kingdom, respectively. The sensitivity exercises suggest that these estimates may be slightly higher for the Euro Area and United States, but the difference is minor and does not change the picture substantially. Loan supply shocks also contributed to drive the evolution of inflation and interest rates in all three economies in specific periods. This appears to be the case, for example, for the decline in inflation in 2009 as well as the declines in the lending rate and short term interest rates from 2008 to 2010.

### 3.4 The role of loan supply shocks during specific recessions and recoveries

As discussed in the previous section, counterfactuals indicate that loan supply shocks appear to have played significant roles in driving both the early 1990s and the 2008/2009 recessions in all three economic areas. This is confirmed by the impulse responses of real GDP especially during the most recent recession in all three economies, as the impact responses are clearly stronger than the average ones (see Charts 12 to 14).[2] By contrast, the difference between the responses during the early 1990s recession do not seem very much different from the average ones. Similar evidence emerges for the responses of loans to loan supply shocks, with stronger impacts observed for the most recent recession, especially for the Euro Area and the United Kingdom, while not much difference can be observed for the early 1990s recession.

A comparison of the responses across recent recessions and the subsequent recoveries -defined here as developments in the four quarters following the trough- suggests that no major asymmetries emerge. However, some differences can be noticed. In particular, in most cases the response of real GDP to loan supply shocks during the recessions discussed and subsequent recoveries appears very similar. Similarly, the responses of loan growth to the loan supply shock are very similar across these recessions and recoveries, with the main exception of the response of loan growth in the United Kingdom in the most recent recovery, which appears to have been clearly stronger than that during the corresponding recession. Thus, there does not seem to emerge evidence of systematic asymmetries across business cycle phases in the response of loan supply shocks, although some significant differences can be detected in few cases.

Beyond counterfactuals and impulse responses during specific business cycle phases, also the series of structural shocks can provide useful information on the role of loan supply shocks around recession periods. Moreover, a visual inspection of these series can provide an indirect way to assess the plausibility of the method adopted to identify loan supply shocks. Indeed, although there is no perfect way to assess whether the shocks identified correspond in fact to exogenous or unexpected changes in loan supply, an informal assessment of their plausibility can be undertaken by observing the series of structural shocks and discussing particular spikes with reference to anecdotal information on real world events. Chart 15 shows the series for the loan supply shocks for all three

[2]Turning points are those identified by the CEPR Euro Area Business Cycle Dating Committee for the Euro Area and the NBER Business Cycle Dating Committee for the United States, while for the United Kingdom they are based on real GDP growth with recessions defined as periods of two or more consecutive negative quarter-on-quarter growth rates.

economic areas. It can be observed that large negative spikes can be found in all three cases in the periods around the default of Lehman Brothers (September 2008), which presumably had an immediate unexpected adverse effect on the balance sheet of most banks, among other effects. For the Euro Area three negative spikes can be seen from 2008Q2 to 2008Q4 and a bigger one n 2009Q1, while for the United Kingdom and the United States two consecutive negative spikes can be found for 2008Q2 and 2008Q3. Moreover, for the United States large negative spikes can also be observed in the early 1990s, in coincidence with the so-called "capital crunch " associated to the early 1990s recession (Bernanke and Lown, 1991; Peek and Rosengren, 1995) and in 1999, in the aftermath of the Long-Term Capital Management crisis.[3] Overall, it can be observed that in all three economies considered a number of consecutive negative spikes can be found during the most of the main recessions. Moreover, these series are in line with a significant role played by adverse loan supply shocks during the early 1990s and 2008/2009 recessions in all three economies.

### 3.5 Sensitivity analysis

In order to assess the robustness of results, we undertake various exercises. First, we examine how the main results change if the identification restrictions are imposed on more than one period, up to four periods. Second, we carry out the analysis estimating the model with only four variables, that is without the short term interest rate which was not used in the identification scheme but was included as a core variable typically included in VARs. Rather than showing how all results change with these modifications we focus on two main sets of results, the average impulse responses and the counterfactuals.

As regards the first sensitivity exercise, Chart 16 shows the average impulse responses (with 68% percentiles) for four cases. In the first, restrictions are imposed only on impact (K=1, baseline model); in the second, restrictions are imposed on impact as well as on one period after that (K=1&2); in the third, restrictions are imposed on impact as well as on first two periods after that (K=1&2&3); and in the fourth restrictions are imposed on impact as well as on subsequent three periods after that (K=1&2&3&4).[4] It can be noticed that results are very similar in all cases across these four sets of restrictions. Chart 17 shows that counterfactuals are also very similar for all variables for all economic

[3]A comparison of the loans supply shocks with available banking survey data would be tempting but would have severe limitations. Indeed, indicators from surveys such as the ECB Bank Lending Survey, the Federal Reserve's Senior Loan Officer Opinion Survey or the Bank of England's Credit Conditions Survey are all endogenous, that is they reflect changes in response to both the economic situation and exogenous changes independent of the latter. Trying to estimate both components is difficult and inevitably affected by high uncertainty, not least due to the short span of the survey indicators.

[4]Note that for the case of the Euro Area results were found only for the first two cases.

area across the four scenarios. Very similar results are found also for average variance decompositions and series of structural shocks to loan supply, with notable spikes in the same periods as discussed above (not shown but available upon request).

As regards the second sensitivity exercise, Chart 18 shows the average impulse responses (with 84% percentiles) for two cases: i) model with five variables and restrictions imposed only on impact (baseline model); ii) model with four variables (i.e. excluding the short term interest rate) and restrictions imposed only on impact. Also in this case the shape, magnitude and uncertainty bands of impulse responses are very similar across the two cases. Similarly, as shown in Chart 19, also the counterfactual are barely distinguishable across the two sets on models. An exception as regards the latter is represented by the counterfactual for loan growth for the US, with the model with four variables pointing to a bigger contribution of loan supply shocks to the decline in loan growth between 2007 and 2009, by about 50% instead of only by about 30% as the counterfactual based on the baseline model suggests. By contrast, the counterfactuals for the Euro Area and the United Kingdom for loan growth are very similar, with only minor differences emerging between the baseline case the 4-variables model case.

## 4 Conclusions

This paper provides some evidence that loan supply shocks have played an important role in business cycle fluctuations in the Euro Area, the United Kingdom and the United States over the past three decades. The model adopted, a time-varying parameters VAR with stochastic volatility, seems to be particularly useful to capture the role of these shocks over the business cycle, as evidence can be found that this role has changed over time. The main results of the empirical analysis are the following. First, loan supply shocks appear to have a significant effect on economic activity and credit markets, but to some extent also inflation, in all three economic areas. At the same time, some differences across geographic areas can also be uncovered. For example, the short term impact on real GDP and loan volumes appears to be stronger in the United States and, especially for loan growth, in the United Kingdom, than in the Euro Area. Second, the impact of these shocks may have changed over time, as for example the short term impact of these shocks on real GDP and loans seems to have increased in all three economic areas over the past few years. Third, it appears that the contribution of loan supply shocks is particulary important during slowdowns. For example, the contribution of these shocks can explain about one half of the decline in annual real GDP growth during 2008 and 2009 in the Euro Area and the United States and possibly about three fourths of that observed in the United Kingdom. Finally, the contribution of loan supply shocks to the decline in the annual growth rate of loans observed from the peaks of 2007 to the troughs of 2009/2010 was slightly less than half of the total decline in the Euro Area and the United States and somewhat more than half of that in the United Kingdom.

## 5 References

Bassett, W. F., M. B. Chosak, J. C. Driscoll and E. Zakrajšek (2010): "Identifying the Macroeconomic Effects of Bank Lending Supply Shocks", mimeo, December 2010, Federal Reserve Board.

Benati, L. (2008): "The "Great Moderation" in the United Kingdom", Journal of Money, Credit and Banking, vol. 40(1), pp. 121-147.

Bernanke, B. and C. Lown (1991): "The credit crunch", Brookings Papers on Economic Activity, vol. 2, pp. 205-247.

Brunnermeier, M. K. (2009): "Deciphering the Liquidity and Credit Crunch 2007-2008," Journal of Economic Perspectives, vol. 23(1), pp. 77-100.

Busch, U., M. Scharnagl and J. Scheithauer (2010): "Loan Supply in Germany During the Financial Crisis", Discussion Paper Series 1 05/2010, Deutsche Bank.

Canova, F. and L. Gambetti (2009): "Structural changes in the US economy: Is there a role for monetary policy?", Journal of Economic Dynamics and Control, vol. 33(2), pp. 477-490.

Ciccarelli, M., A. Maddaloni and J.-L. Peydró (2010): "Trusting the bankers: a new look at the credit channel of monetary policy", ECB Working Paper n. 1228, July 2010.

Cogley, T. and T. J. Sargent (2005): "Drift and Volatilities: Monetary Policies and Outcomes in the Post WWII U.S.", Review of Economic Dynamics, vol. 8(2), pp. 262-302.

D'Agostino, A., L. Gambetti and D. Giannone (2011): "Macroeconomic Forecasting and Structural Change", Journal of Applied Econometrics (forthcoming).

De Nicolò, G. and M. Lucchetta (2011): "Systemic Risks and the Macroeconomy," NBER Working Paper 16998, April 2011.

Diamond, D. W. and R. G. Rajan (2009): "The Credit Crisis: Conjectures about Causes and Remedies," American Economic Review, vol. 99(2), pp.606-10.

Fernández-Villaverde, F. and J. F. Rubio-Ramírez (2010): "Macroeconomics and Volatility: Data, Models, and Estimation," NBER Working Papers 16618.

Galí, J. and L. Gambetti (2009): "On the Sources of the Great Moderation," American Economic Journal: Macroeconomics, vol. 1(1), pp. 26-57.

Gilchrist, S. and E. Zakrajšek (2011): "Monetary Policy and Credit Supply Shocks," IMF Economic Review, vol. 59(2), pp. 195-232.

Gorton, G. B. (2009): "The panic of 2007", in Maintaining stability in a changing financial system, Proceedings of the 2008 Jackson Hole Conference.

Hristov, N., O. Hülsewig and T. Wollmershäuser (2011): "Loan Supply Shocks during the Financial Crisis: Evidence for the Euro Area", CESifo Working Paper Nr. 3395, 2011.

Lown, C. and D. P. Morgan (2006): "The Credit Cycle and the Business Cycle: New Findings Using the Loan Officer Opinion Survey," Journal of Money, Credit and Banking, vol. 38(6), pp. 1575-97.

Musso, A. (2009): "Money and credit over the business cycle", mimeo, April 2009, European Central Bank.

Peek, J. and E. Rosengren (1995): "The Capital Crunch: Neither a Borrower nor a Lender Be," Journal of Money, Credit and Banking, vol. 27(3), pp. 625-38.

Primiceri, G. (2005): "Time Varying Structural Vector Autoregressions and Monetary Policy ", The Review of Economic Studies, vol. 72, pp. 821-852.

Rubio-Ramirez, J. F., D. F. Waggoner and T. Zha (2010): "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference," Review of Economic Studies, vol. 77(2), pp. 665-96.

**Appendix A - Estimation**

Estimation is done using Bayesian methods. To draw from the joint posterior distribution of model parameters we use a Gibbs sampling algorithm along the lines described in Primiceri (2005). The basic idea of the algorithm is to draw sets of coefficients from known conditional posterior distributions. The algorithm is initialized at some values and, under some regularity conditions, the draws converge to a draw from the joint posterior after a burn in period. Let $z$ be $(q \times 1)$ vector, we denote $z^T$ the sequence $[z_1', ..., z_T']'$. Each repetition is composed of the following steps:

1. $p(\sigma^T|x^T, \theta^T, \phi^T, \Omega, \Xi, \Psi, s^T)$
2. $p(s^T|x^T, \theta^T, \sigma^T, \phi^T, \Omega, \Xi, \Psi)$[5]
3. $p(\phi^T|x^T, \theta^T, \sigma^T, \Omega, \Xi, \Psi, s^T)$
4. $p(\theta^T|x^T, \sigma^T, \phi^T, \Omega, \Xi, \Psi, s^T)$
5. $p(\Omega|x^T, \theta^T, \sigma^T, \phi^T, \Xi, \Psi, s^T)$
6. $p(\Xi|x^T, \theta^T, \sigma^T, \phi^T, \Omega, \Psi, s^T)$
7. $p(\Psi|x^T, \theta^T, \sigma^T, \phi^T, \Omega, \Xi, s^T)$

**Gibbs sampling algorithm**

• Step 1: sample from $p(\sigma^T|y^T, \theta^T, \phi^T, \Omega, \Xi, \Psi, s^T)$

To draw $\sigma^T$ we use the algorithm of Kim, Shephard and Chibb (KSC) (1998). Consider the system of equations $y_t^* \equiv F_t^{-1}(y_t - X_t'\theta_t) = D_t^{1/2}u_t$, where $u_t \sim N(0, I)$, $X_t = (I_n \otimes x_t')$, and $x_t = [1_n, y_{t-1}...y_{t-p}]$. Conditional on $y^T, \theta^T$, and $\phi^T$, $y_t^*$ is observable. Squaring and taking the logarithm, we obtain

$$y_t^{**} = 2r_t + \upsilon_t \tag{7}$$

$$r_t = r_{t-1} + \xi_t \tag{8}$$

where $y_{i,t}^{**} = \log((y_{i,t}^*)^2 + 0.001)$ - the constant (0.001) is added to make estimation more robust - $\upsilon_{i,t} = \log(u_{i,t}^2)$ and $r_t = \log \sigma_{i,t}$. Since, the innovation in (7) is distributed as $\log \chi^2(1)$, we use, following KSC, a mixture of 7 normal densities with component probabilities $q_j$, means $m_j - 1.2704$, and variances $v_j^2$ ($j$=1,...,7) to transform the system in a Gaussian one, where $\{q_j, m_j, v_j^2\}$ are chosen to match the moments of the $\log \chi^2(1)$ distribution. The values are:

[5] See below the definition of $s^T$.

Table A1: Parameters Specification

| $j$ | $q_j$ | $m_j$ | $v_j^2$ |
|---|---|---|---|
| 1.0000 | 0.0073 | -10.1300 | 5.7960 |
| 2.0000 | 0.1056 | -3.9728 | 2.6137 |
| 3.0000 | 0.0000 | -8.5669 | 5.1795 |
| 4.0000 | 0.0440 | 2.7779 | 0.1674 |
| 5.0000 | 0.3400 | 0.6194 | 0.6401 |
| 6.0000 | 0.2457 | 1.7952 | 0.3402 |
| 7.0000 | 0.2575 | -1.0882 | 1.2626 |

Let $s^T = [s_1, ..., s_T]'$ be a matrix of indicators selecting the member of the mixture to be used for each element of $\upsilon_t$ at each point in time. Conditional on $s^T$, $(\upsilon_{i,t}|s_{i,t} = j) \sim N(m_j - 1.2704, v_j^2)$. Therefore we can use the algorithm of Carter and Kohn (1994) to draw $r_t$ ($t$=1,...,T) from $N(r_{t|t+1}, R_{t|t+1})$, where $r_{t|t+1} = E(r_t|r_{t+1}, y^t, \theta^T, \phi^T, \Omega, \Xi, \Psi, s^T, )$ and $R_{t|t+1} = Var(r_t|r_{t+1}, y^t, \theta^T, \phi^T, \Omega, \Xi, \Psi, s^T)$.

- Step 2: sample from $p(s^T|y^T, \theta^T, \sigma^T, \phi^T, \Omega, \Xi, \Psi)$

Conditional on $y_{i,t}^{**}$ and $r^T$, we independently sample each $s_{i,t}$ from the discrete density defined by $Pr(s_{i,t} = j|y_{i,t}^{**}, r_{i,t}) \propto f_N(y_{i,t}^{**}|2r_{i,t} + m_j - 1.2704, v_j^2)$, where $f_N(y|\mu, \sigma^2)$ denotes a normal density with mean $\mu$ and variance $\sigma^2$.

- Step 3: sample from $p(\phi^T|y^T, \theta^T, \sigma^T, \Omega, \Xi, \Psi, s^T)$

Consider again the system of equations $F_t^{-1}(y_t - X_t'\theta_t) = F_t^{-1}\hat{y}_t = D_t^{1/2}u_t$. Conditional on $\theta^T$, $\hat{y}_t$ is observable. Since $F_t^{-1}$ is lower triangular with ones in the main diagonal, each equation in the above system can be written as

$$\hat{y}_{1,t} = \sigma_{1,t}u_{1,t} \quad (9)$$

$$\hat{y}_{i,t} = -\hat{y}_{[1,i-1],t}\phi_{i,t} + \sigma_{i,t}u_{i,t} \quad i = 2, ..., n \quad (10)$$

where $\sigma_{i,t}$ and $u_{i,t}$ are the $i$th elements of $\sigma_t$ and $u_t$ respectively, $\hat{y}_{[1,i-1],t} = [\hat{y}_{1,t}, ..., \hat{y}_{i-1,t}]$. Under the block diagonality of $\Psi$, the algorithm of Carter and Kohn (1994) can be applied equation by equation, obtaining draws for $\phi_{i,t}$ from a $N(\phi_{i,t|t+1}, \Phi_{i,t|t+1})$, where $\phi_{i,t|t+1} = E(\phi_{i,t}|\phi_{i,t+1}, y^t, \theta^T, \sigma^T, \Omega, \Xi, \Psi)$ and $\Phi_{i,t|t+1} = Var(\phi_{i,t}|\phi_{i,t+1}, y^t, \theta^T, \sigma^T, \Omega, \Xi, \Psi)$.

- Step 4: sample from $p(\theta^T|y^T, \sigma^T, \phi^T, \Omega, \Xi, \Psi, s^T)$

Conditional on all other parameters and the observables we have

$$y_t = X_t'\theta_t + \varepsilon_t \quad (11)$$

$$\theta_t = \theta_{t-1} + \omega_t \quad (12)$$

Draws for $\theta_t$ can be obtained from a $N(\theta_{t|t+1}, P_{t|t+1})$, where $\theta_{t|t+1} = E(\theta_t|\theta_{t+1}, y^T, \sigma^T, \phi^T, \Omega, \Xi, \Psi)$ and $P_{t|t+1} = Var(\theta_t|\theta_{t+1}, y^T, \sigma^T, \phi^T, \Omega, \Xi, \Psi)$ are obtained with the algorithm of Carter and Kohn (1994).

- Step 5: sample from $p(\Omega|y^T, \theta^T, \sigma^T, \phi^T, \Xi, \Psi, s^T)$

Conditional on the other coefficients and the data, $\Omega$ has an Inverse-Wishart posterior density with scale matrix $\Omega_1^{-1} = (\Omega_0 + \sum_{t=1}^T \Delta\theta_t(\Delta\theta_t)')^{-1}$ and degrees of freedom $df_{\Omega_1} = df_{\Omega_0} + T$, where $\Omega_0^{-1}$ is the prior scale matrix, $df_{\Omega_0}$ are the prior degrees of freedom and $T$ is length of the sample use for estimation. To draw a realization for $\Omega$ make $df_{\Omega_1}$ independent draws $z_i$ ($i$=1,...,$df_{\Omega_1}$) from $N(0, \Omega_1^{-1})$ and compute $\Omega = (\sum_{i=1}^{df_{\Omega_1}} z_i z_i')^{-1}$ (see Gelman et. al., 1995).

- Step 6: sample from $p(\Xi_{i,i}|y^T, \theta^T, \sigma^T, \phi^T, \Omega, \Psi, s^T)$

Conditional the other coefficients and the data, $\Xi$ has an Inverse-Wishart posterior density with scale matrix $\Xi_1^{-1} = (\Xi_0 + \sum_{t=1}^T \Delta \log \sigma_t(\Delta \log \sigma_t)')^{-1}$ and degrees of freedom $df_{\Xi_1} = df_{\Xi_0} + T$ where $\Xi_0^{-1}$ is the prior scale matrix and $df_{\Xi_0}$ the prior degrees of freedom. Draws are obtained as in step 5.

- Step 7: sample from $p(\Psi|y^T, \theta^T, \sigma^T, \phi^T, \Omega, \Xi, s^T)$.

Conditional on the other coefficients and the data, $\Psi_i$ has an Inverse-Wishart posterior density with scale matrix $\Psi_{i,1}^{-1} = (\Psi_{i,0} + \sum_{t=1}^T \Delta\phi_{i,t}(\Delta\phi_{i,t})')^{-1}$ and degrees of freedom $df_{\Psi_{i,1}} = df_{\Psi_{i,0}} + T$ where $\Psi_{i,0}^{-1}$ is the prior scale matrix and $df_{\Psi_{i,0}}$ the prior degrees of freedom. Draws are obtained as in step 5 for all $i$.

We make 15000 repetitions discarding the first 10000 and collecting one out of five draws.

### Appendix B - Data

The following paragraphs provide details on the data definitions, sources and treatment.

### Real GDP

Euro area: Gross domestic product at market price, Chain linked, ECU/euro, Seasonally and working day adjusted, Euro area 16 fixed composition, ESA95 National Accounts (see ECB's Statistical Data Warehouse, SDW, code: ESA.Q.I5.S.0000.B1QG00.1000. TTTT.L.U.R, see http://sdw.ecb.europa.eu/), from 1996Q1 onwards. Extended backwards using (the growth rates of) the Area-Wide Model database series YER (real GDP) (10th update, September 2010, downloadable from the Euro Area Business Cycle Network, EABCN, www.eabcn.org). Sources: Eurostat and Area-Wide Model database.

United Kingdom: Gross domestic product at market price, Chain linked volumes, reference year 2000, National currency, Working day and seasonally adjusted, United Kingdom, ESA95 National Accounts (see ECB's Statistical Data Warehouse, SDW, code: ESA.Q.GB.Y.0000.B1QG00.1000.TTTT.L.N.A, see http://sdw.ecb.europa.eu/). Sources: Eurostat.

United States: Real Gross Domestic Product, Billions of Chained 2005 Dollars, Quarterly, Seasonally Adjusted, downloaded from Fred II (GDPC96), see http://research.stlouisfed.org/fred2/. Sources: U.S. Department of Commerce: Bureau of Economic Analysis.

### Consumer prices

Euro area: Harmonised index of consumer prices (HICP), Euro area (changing composition), quarterly averages of monthly index, backdated, ECU (to 1989) & fixed euro conversion rate (from 1990) used for weights, Seasonally adjusted, not working day adjusted (see ECB's Statistical Data Warehouse, SDW, code: ICP.M.U2.S.000000.3.ECX, see http://sdw.ecb.europa.eu/), ECB calculation based on national and Eurostat data. Sources: European Central Bank and Eurostat.

United Kingdom: General index of retail prices (RPI), all items, unadjusted, average of monthly index, United Kingdom. Own seasonal adjustment by X12 ARIMA (via GiveWin). Downloaded from dataset BISM: BIS Macro-economic series (Blocks A-K, Q-W), BIS code: BISM.M.VEBA.GB.01. For more details on the data see www.statistics.gov.uk/hub/index.html. Sources: United Kingdom Office for National Statistics.

United States: Consumer Price Index for All Urban Consumers: All Items, seasonally adjusted, downloaded from Fred II (CPIAUCSL), see http://research.stlouisfed.org/fred2/. Sources: U.S. Department of Labor: Bureau of Labor Statistics.

**Short term interest rates**

Euro area: EMU 3-month EURIBOR, historical close, average of observations through period (see ECB's Statistical Data Warehouse, SDW, code: FM.M.U2.EUR.RT.MM. EURIBOR3MD_.HSTA, see http://sdw.ecb.europa.eu/), ECB calculation based on data provided by Reuters, from 1994 until 2006. Extended backwards using the Area-Wide Model database series STN (Nominal Short-Term Interest Rate) (10th update, September 2010, downloadable from the Euro Area Business Cycle Network, EABCN, www.eabcn.org). From 2007 onwards Euro benchmark 3-month Euro Repo, provided by DataStream. Sources: European Central Bank, DataStream, Reuters and Area-Wide Model database.

United Kingdom: 3-month (91-days) rate on Treasury Bills, average allotment rate, end-of-period rate, United Kingdom. Downloaded from dataset BISM: BIS Macroeconomic series (Blocks A-K, Q-W), BIS code: BISM.M.HEPA.GB.01. For more details on the data see www.statistics.gov.uk/hub/index.html. Sources: United Kingdom Office for National Statistics.

United States: 3-Month Treasury Bill: Secondary Market Rate, average of monthly data, downloaded from Fred II (TB3MS), see http://research.stlouisfed.org/fred2/. Sources: Board of Governors of the Federal Reserve System.

**Loans to the non-financial private sector**

Euro area: Sum of (nominal) outstanding amounts of loans to households and loans to non-financial corporations, derived by rescaling indices of notional stocks with base equal to the outstanding amounts for 2010Q1. Series adjusted to include loan sales and securitisation from 2003Q1 onwards (until 2008Q4 on the basis of a "best estimate" and from 2009Q1 onwards using the new harmonised ECB monetary and financial statistics; see the box on "The impact of loan sales and securitisation activity on recent developments in MFI loans to non-financial corporations and households" in the July 2011 issue of the ECB Monthly Bulletin). Sources: Own calculations based on data from the European Central Bank.

United Kingdom: Sum of (nominal) monthly amounts outstanding of monetary financial institutions' sterling net lending excluding securitisations to household sector and to non-financial corporations (in sterling millions), seasonally adjusted. Bank of England Statistical Interactive Database codes: LPMBC44 and LPMBC57 (see www.bankofengland.co.uk/mfsd/iadb/NewIntermed.asp). Sources: Bank of England.

United States: Sum of (nominal) outstanding amounts (billions of dollars) of loans to households (Flow of Funds definitions and codes: "Households and nonprofit organizations; credit market instruments; liability" FL154104005.q minus "Nonprofit organizations; municipal securities and loans; liability" FL163162005.q) and loans to non-financial corporations (Flow of Funds definitions and codes: "Nonfinancial business; credit market instruments; liability" FL144104005.q minus "Nonfarm nonfinancial corporate business; commercial paper; liability" FL103169100.q, "Nonfarm nonfinancial corporate business; municipal securities and loans; liability" FL103163003.q and "Nonfarm nonfinancial corporate business; corporate bonds; liability" FL103162005.q). Downloaded from www.federalreserve.gov/releases/z1/ current/. Sources: Flow of Funds Accounts of the United States, Board of Governors of the Federal Reserve System.

**Composite lending rates**

Euro area: Composite lending rate, derived as weighted average of interest rates charged on loans to households and loans to non-financial corporations, with weights based on the nominal outstanding amounts (or, if not available, flows) of loans to households and to non-financial corporations. Sources: Own calculations based on data from the European Central Bank.

United Kingdom: Composite lending rate, derived as weighted average of interest rates charged on loans to households and loans to non-financial corporations, with weights based on the nominal outstanding amounts of loans to households and to non-financial corporations. Composite lending rate for non-financial corporations derived from quarterly average of UK resident monetary financial institutions' (excl. Central Bank) sterling weighted average interest rate on other loans, new advances to private non-financial corporations (in percent), not seasonally adjusted (Bank of England Statistical Interactive Database code: CFMBJ82, see www.bankofengland.co.uk/ mfsd/iadb/NewIntermed.asp) from 2004Q1 onwards; extended backwards to 1999Q1 using the (first difference of) quarterly average of UK resident monetary financial institutions' (excl. Central Bank) sterling weighted average interest rate, other loans to private non-financial corporations (in percent), not seasonally adjusted (Bank of England Statistical Interactive Database code: CFMHSDC, see www.bankofengland.co.uk/ mfsd/iadb/NewIntermed.asp); extended backwards using Bank of England estimates for corporate bond rate. Composite lending rate for households derived as composite of lending rate of mortgage rate (IUMTLMV, see www.bankofengland.co.uk/ mfsd/iadb/ NewIntermed.asp, from 1995Q1 onwards, extended back using differences in BIS data - average of mortgage rates by building societies and retail banks- until 1985Q1, extended back using differences in Council of Mortgage Lenders, CML, building societies basic mortgage rate), personal loan rate (IUMHPTL, see www.bankofengland.co.uk/ mfsd/iadb/NewIntermed.asp, from 1995Q1 onwards, extended back using differences in Bank of England estimates for personal loan rates data) and credit card rate (IUMCCTL, see www.bankofengland.co.uk/ mfsd/iadb/NewIntermed.asp, from 1995Q1 onwards, extended back using differences in Bank of England estimates for credit card rates data), with weights based on outstanding amounts of corresponding loan categories. Sources: Own calculations based on data from the Bank of England.

United States: Composite lending rate, derived as weighted average of interest rates charged on loans to households and loans to non-financial corporations, with weights based on the nominal outstanding amounts of loans to households and to non-financial corporations. Composite lending rate for non-financial corporations derived as average of bank prime loan rate prime rate on short-term business loans (Fred II: MPRIME, see http:// research.stlouisfed.org/fred2/) and commercial and industrial loan rate (Board of Governors of the Federal Reserve System E.2 SURVEY OF TERMS OF BUSINESS LENDING, see http://www.federalreserve.gov/ releases/e2/) from 1986Q1 onwards, extended backwards using the (first difference of) the bank prime loan rate prime rate on short-term business loans (Fred II: MPRIME, see http://research.stlouisfed.org/fred2/). Composite lending rate for households derived as composite of lending rate of mortgage rate (30-Year Conventional Mortgage Rate, Fred II: MORTG, see http:// research.stlouisfed.org/fred2/) and personal loan rate (average of interest rate on 48-month new car loans: G19/TERMS/RIFLPBCIANM48_N.M, interest rate on 24-month personal loans: G19/TERMS/RIFLPBCIPLM24_N.M and interest rate on credit card plans - all accounts: G19/TERMS/RIFSPBCICC_N.M, from 1994Q4 onwards, extended backwards using changes in average of interest rate on first two loans, see www.federalreserve.gov/releases/g19/hist/), with weights based on outstanding amounts of corresponding loan categories. Sources: Own calculations based on data from the Board of Governors of the Federal Reserve System.

# Tables

## Table 1 – Identification restrictions

| | SHORT RUN RESPONSES TO AN EXPANSIONARY SHOCK | | | | |
|---|---|---|---|---|---|
| SHOCK | real GDP | inflation | loans | lending rate | short term interest rate |
| Aggregate supply | + | - | + | + | no restriction |
| Aggregate demand | + | + | + | + | no restriction |
| Loan supply | + | no restriction | + | - | no restriction |

Note: Sign imposed on the impulse response on impact of all variables for the case of a shock causing an increase in real GDP.

## Table 2 – Trace tests

| | 16% perc. | 50% perc. | 84% perc. | trace(Q0) |
|---|---|---|---|---|
| Euro area | 0.938 | 1.458 | 2.240 | 0.016 |
| United Kingdom | 0.917 | 1.299 | 1.864 | 0.076 |
| United States | 3.380 | 5.008 | 7.303 | 0.076 |

Note: The first three columns show the 16%, 50% and 84% percentiles of the posterior of the trace of the variance-covariance matrix of the error term of the law of motion of the parameters of the VAR while the fourth column shows the trace of the prior variance-covariance matrix. Following Cogley and Sargent (2005), since the value of the trace of the prior variance-covariance matrix is smaller that even the 16% percentile, this can be interpreted as evidence pointing to the presence of time variation in the parameters of the VAR (i.e. the sample points towards greater time variation in the parameters than that of the prior selected).

# Charts

**Chart 1 - Data**

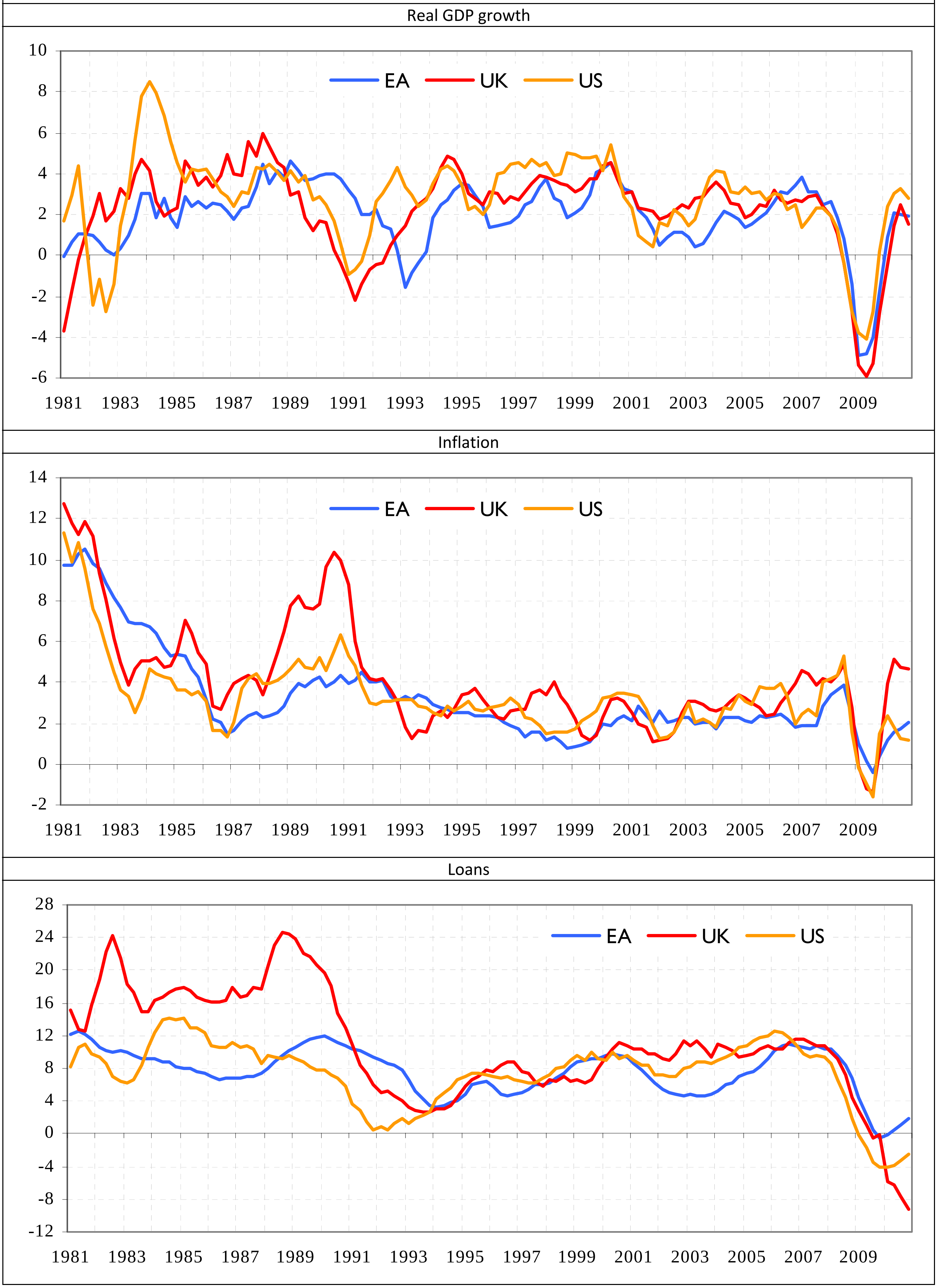
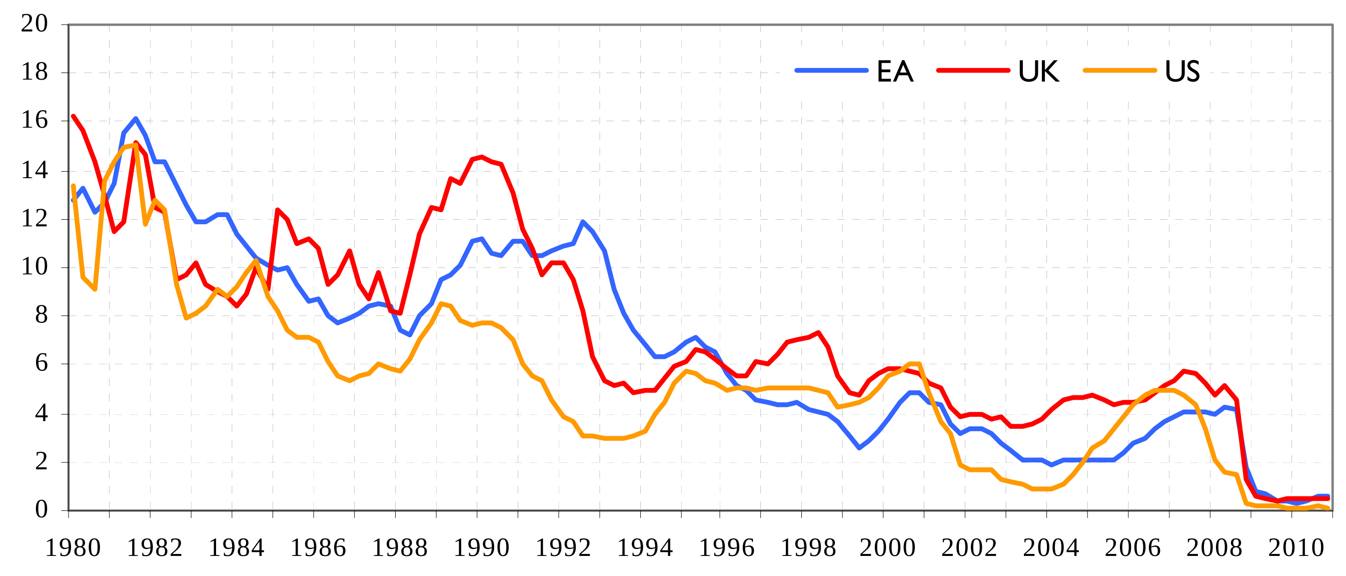
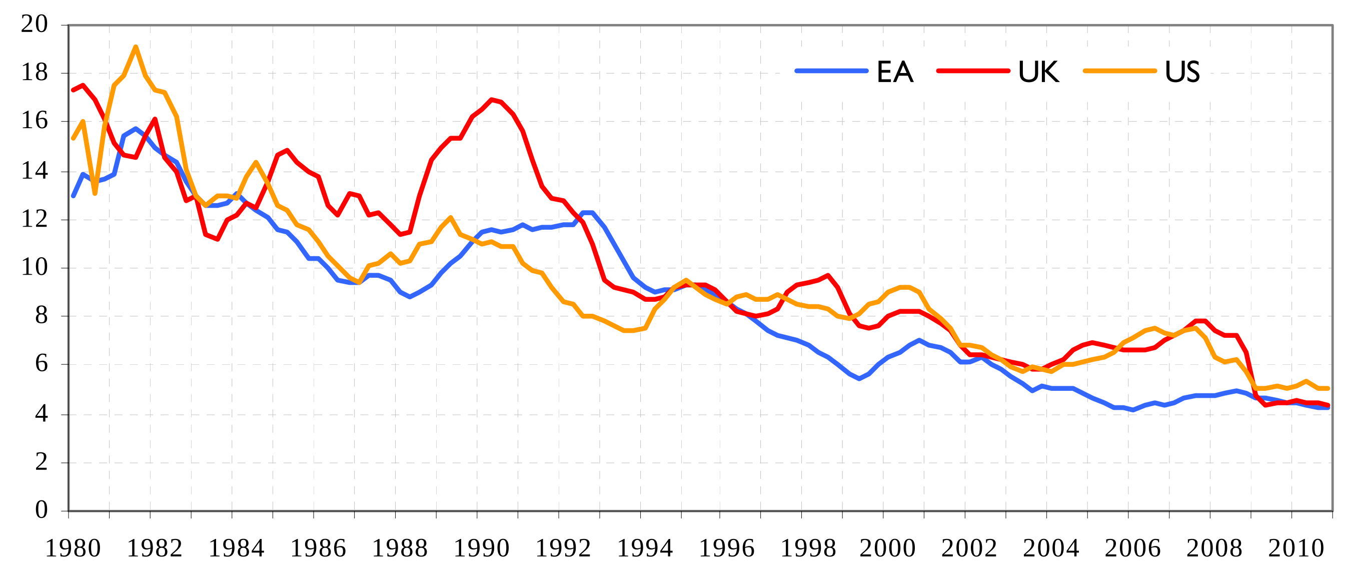


**Chart 1 - Data (continued)**

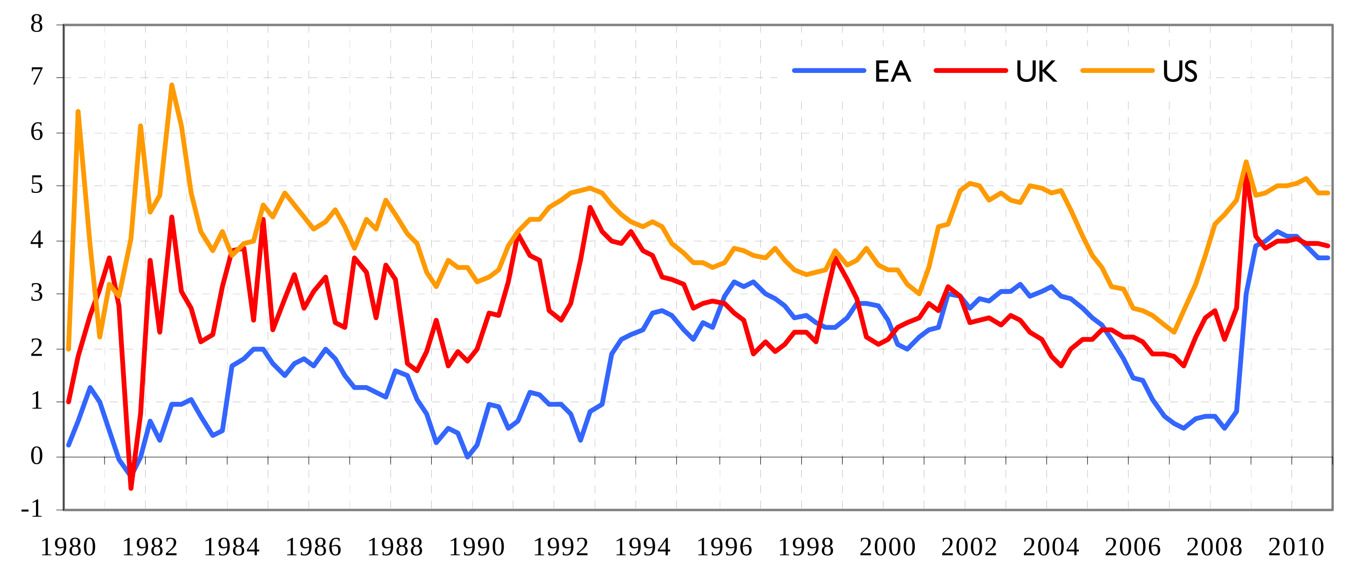
Short term interest rate




Composite lending rate



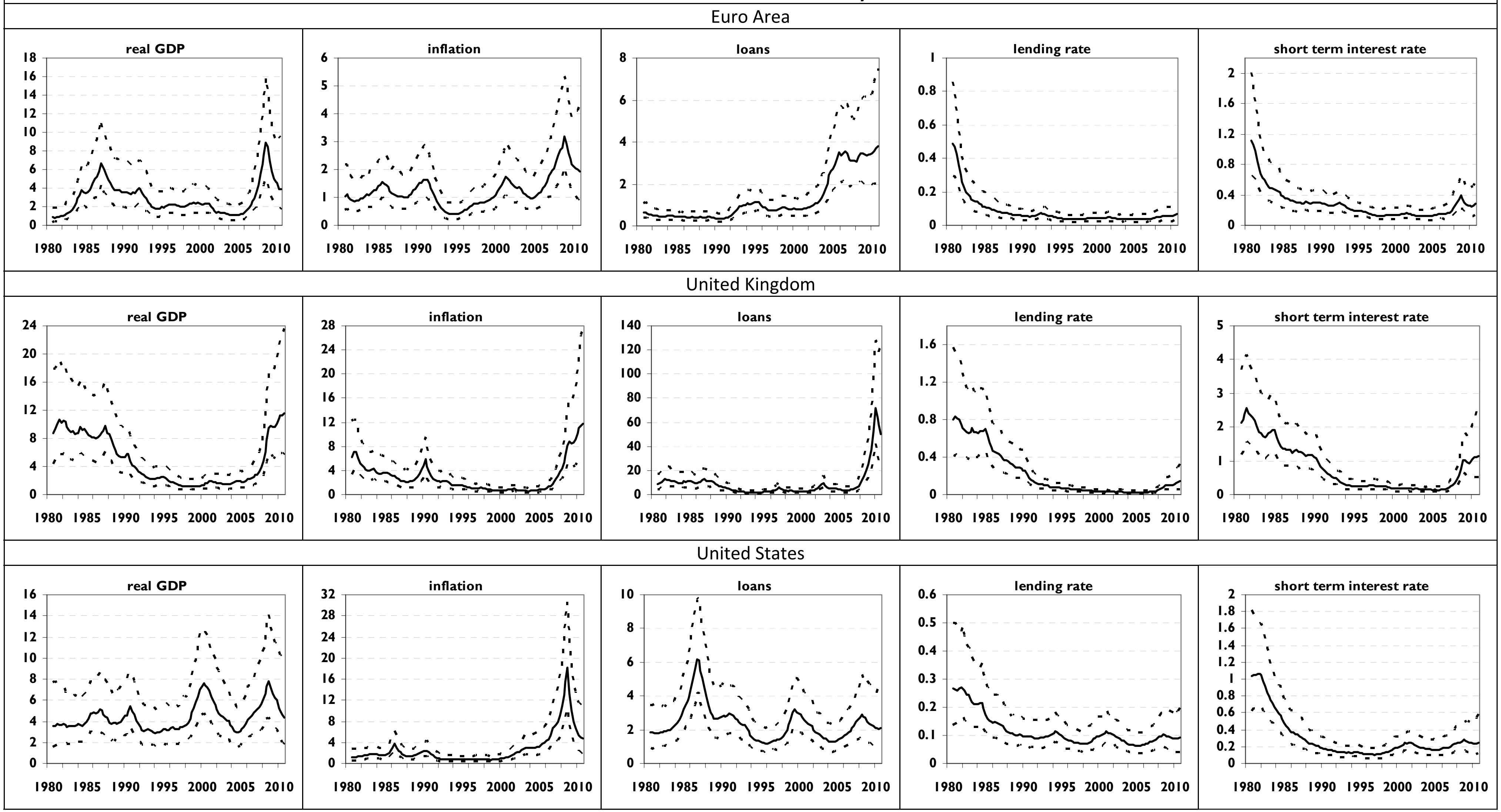

Spread (composite lending rate – short term interest rate)




Sources: Bank of England, EABCN, ECB, Eurostat, UK ONS, US BEA, US Board of Governors.

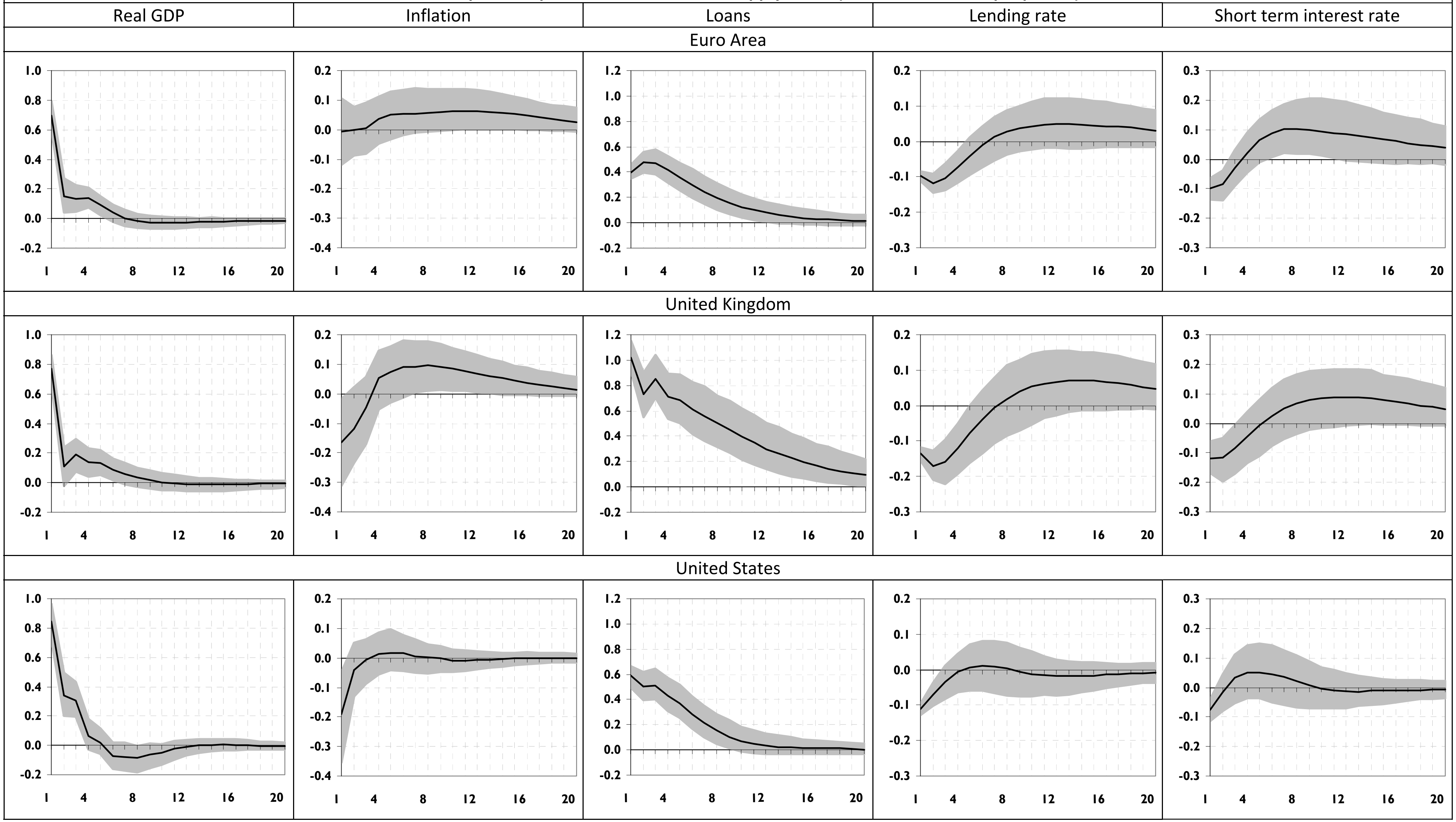
Note: See Appendix A for details on data sources, definitions and treatment.

**Chart 2 - Stochastic volatility**



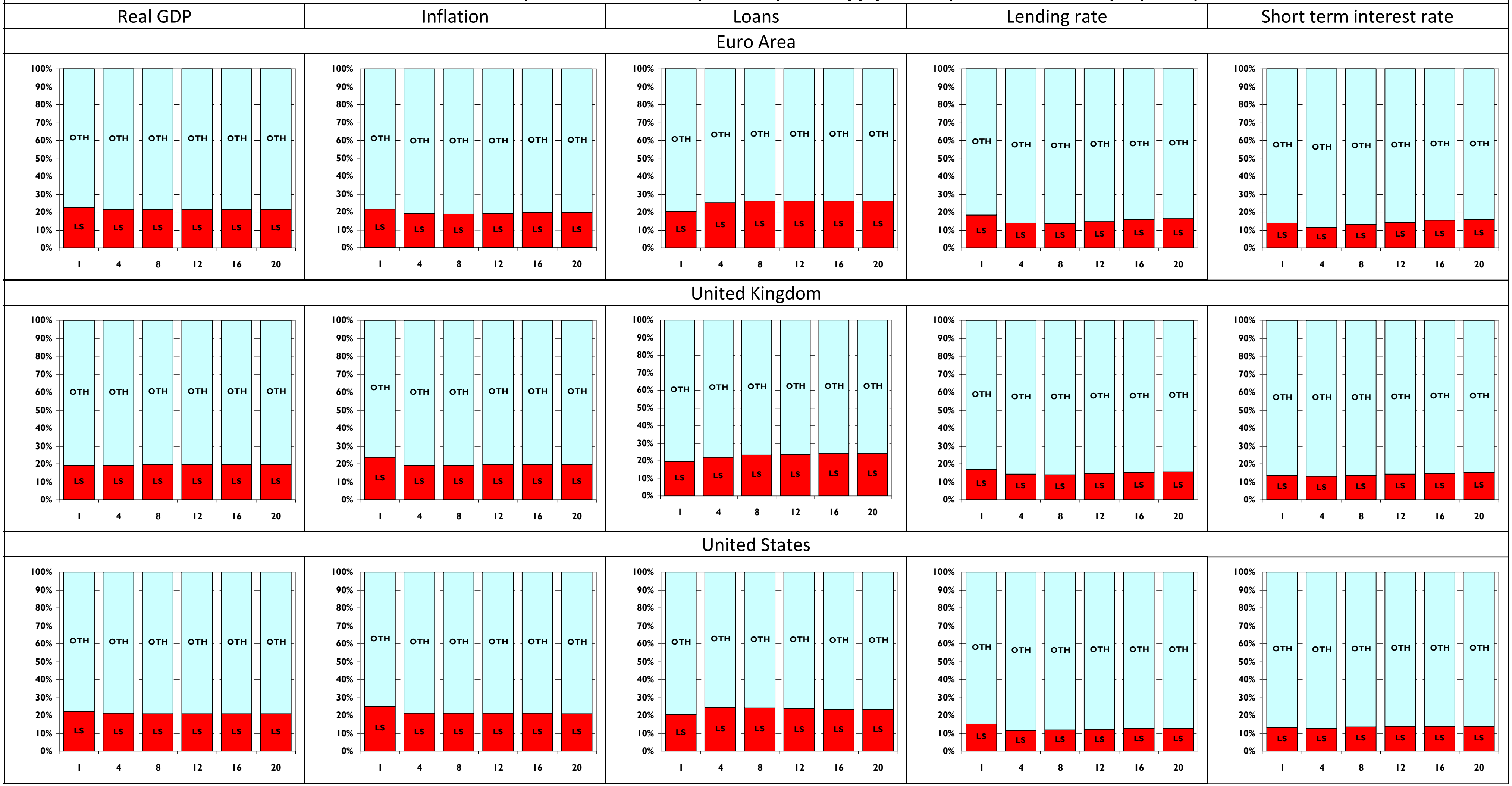

Note: Residual time-varying variances, median, 16% and 84% percentiles.

**Chart 3 - Impulse response functions to loan supply shock (median whole sample period)**



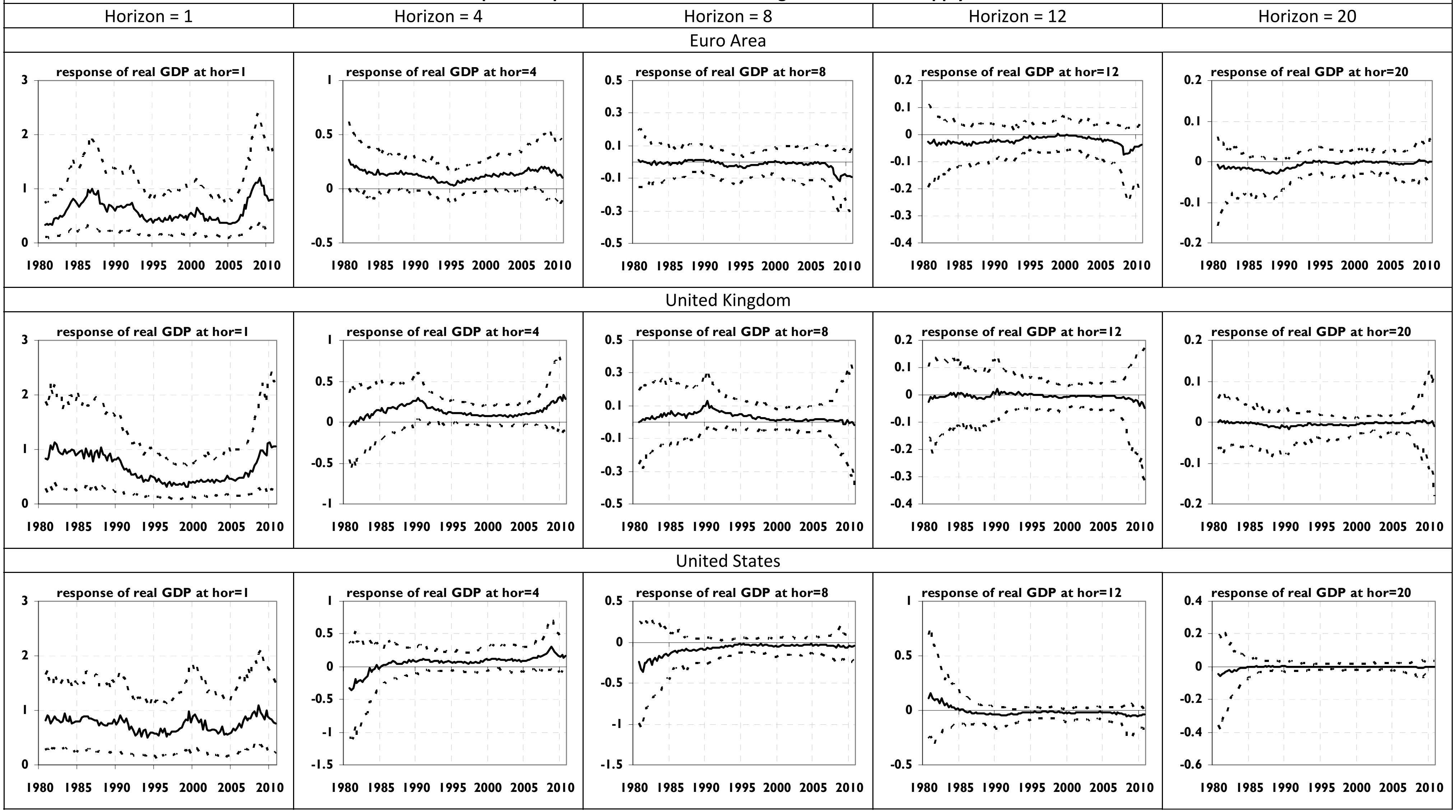

Note: Averages of impulse response functions over time. Line is the median, grey are delimits the space between the 16% and 84% percentiles.

**Chart 4 – Variance decomposition: fractions explained by loan supply shocks (median whole sample period)**



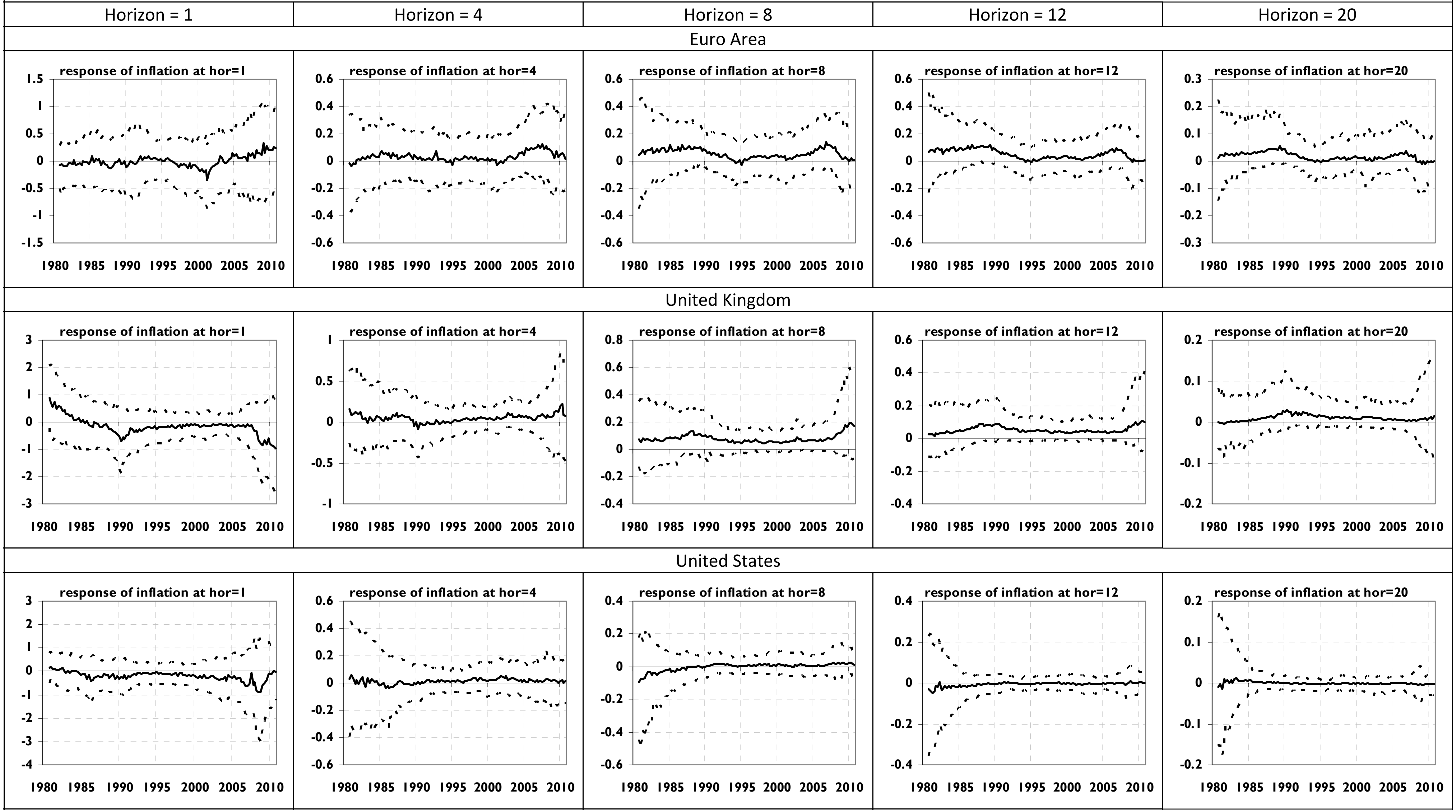

Note: Fractions of variances of each variables explained by loan supply shocks at various horizons. "LS" stands for fraction of variance explained by loans supply shocks, while "OTH" stands for fraction of variance explained by other shocks.

**Chart 5 – Evolution of impulse response functions of real GDP growth to a loan supply shock at various horizons**



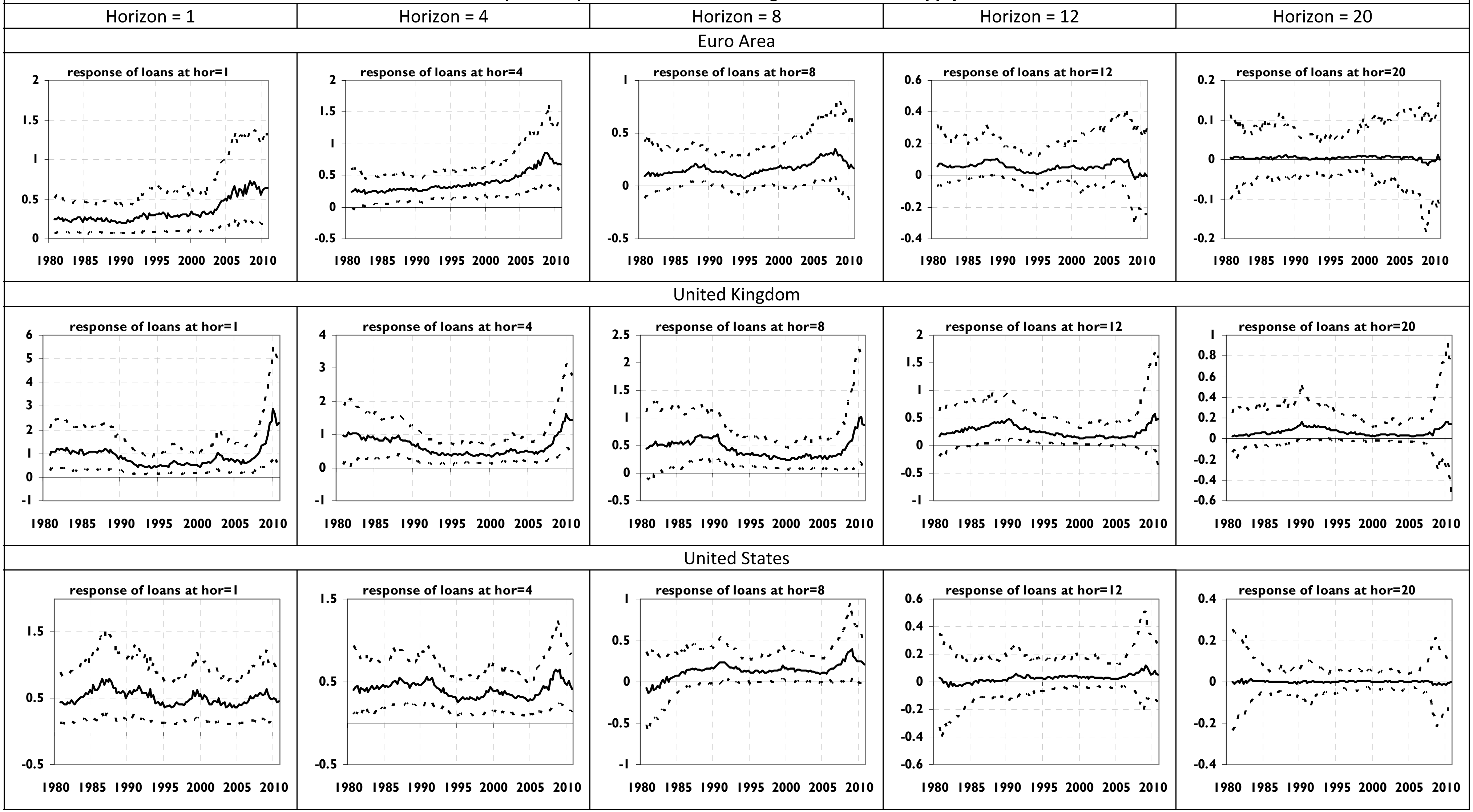

Note: Evolution of impulse responses of real GDP growth to a loan supply shock at specific horizons over time, median, 16% and 84% percentiles.

**Chart 6 – Evolution of impulse response functions of inflation to a loan supply shock at various horizons**



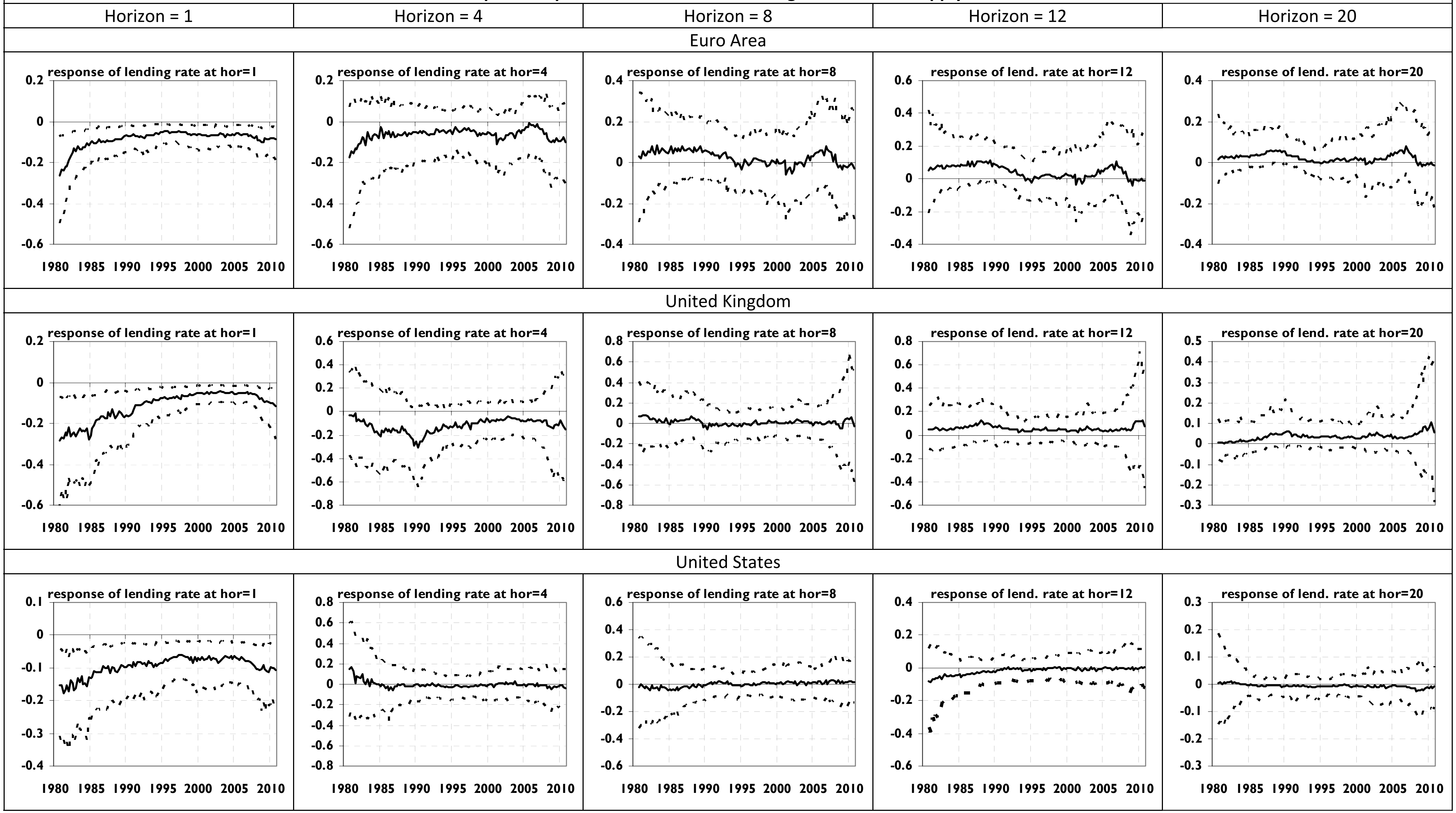

Note: Evolution of impulse responses of inflation to a loan supply shock at specific horizons over time, median, 16% and 84% percentiles.

**Chart 7 – Evolution of impulse response functions of loan growth to a loan supply shock at various horizons**



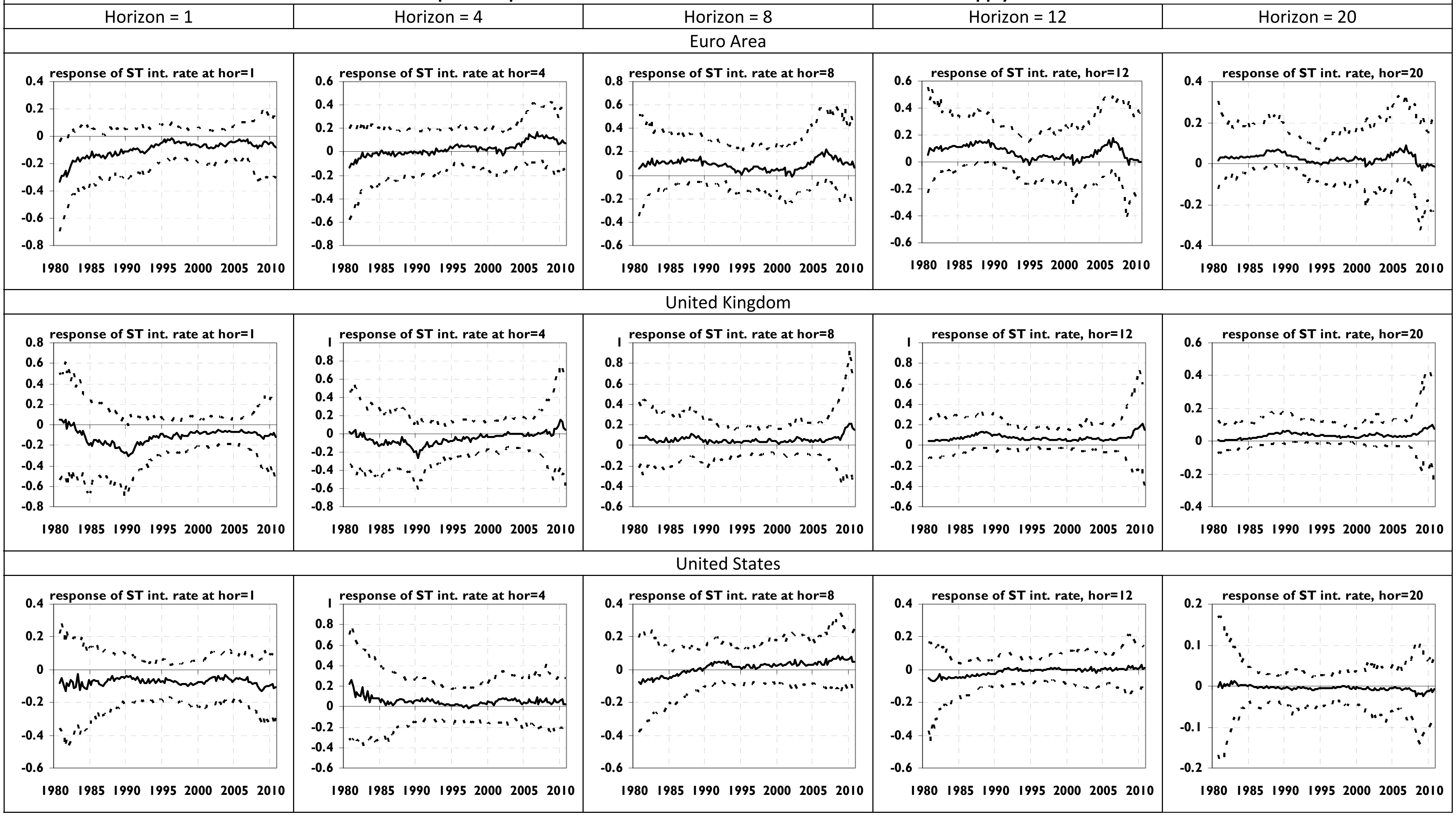

Note: Evolution of impulse responses of loan growth to a loan supply shock at specific horizons over time, median, 16% and 84% percentiles.

**Chart 8 – Evolution of impulse response functions of the lending rate to a loan supply shock at various horizons**



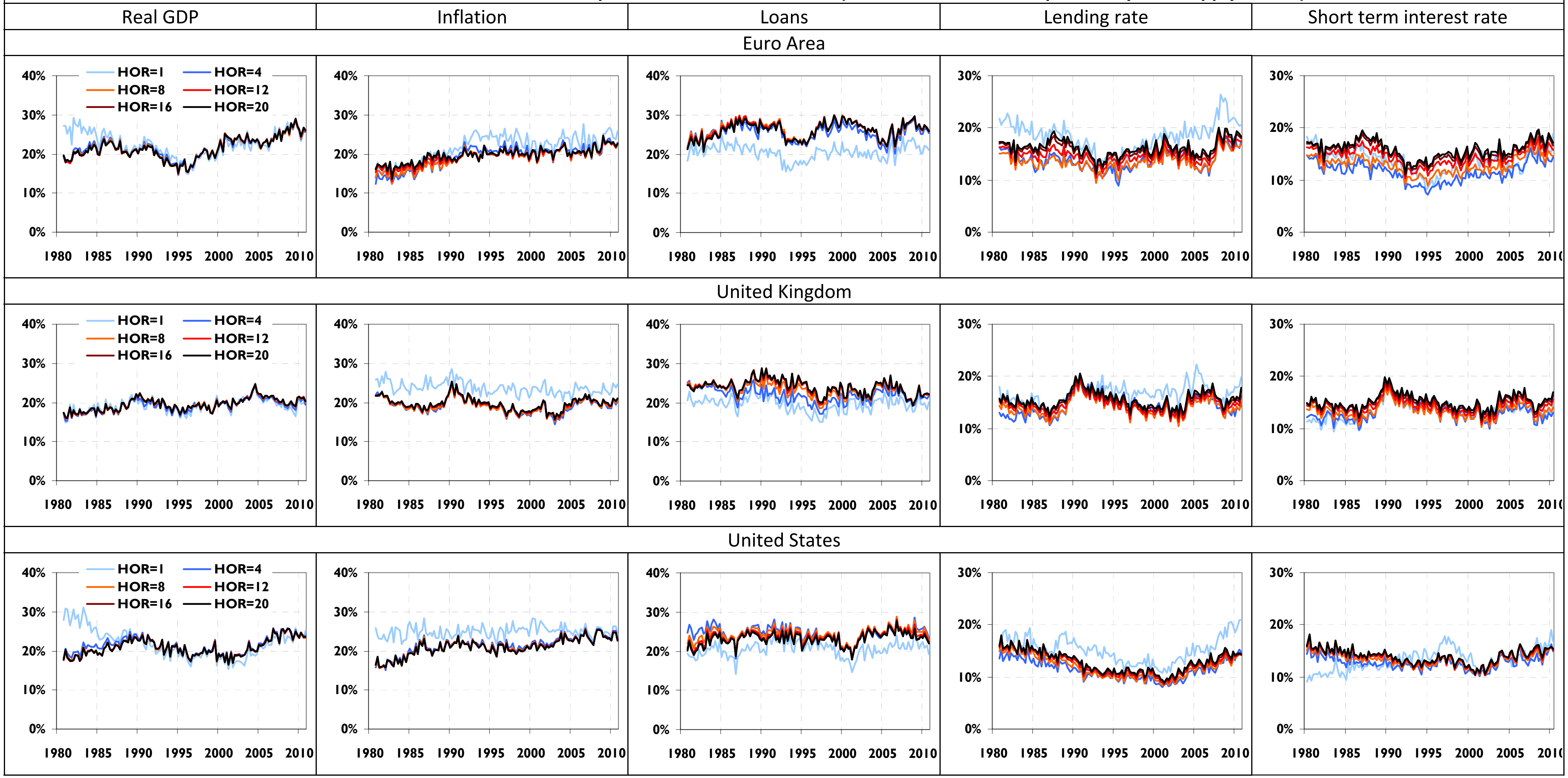

Note: Evolution of impulse responses of lending rate to a loan supply shock at specific horizons over time, median, 16% and 84% percentiles.

**Chart 9 – Evolution of impulse response functions of the short term interest rate to a loan supply shock at various horizons**



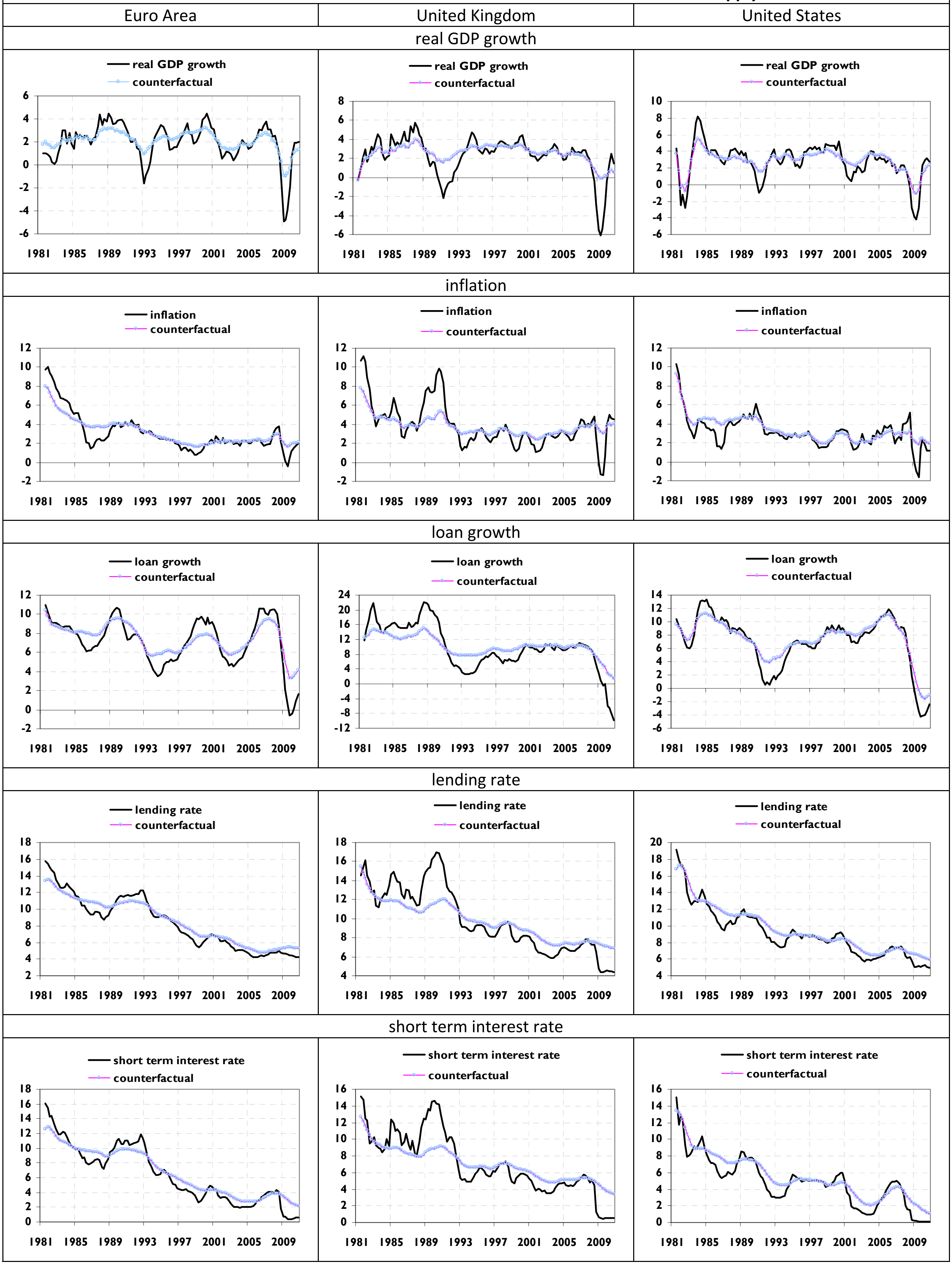

Note: Evolution of impulse responses of short term interest rate to a loan supply shock at specific horizons over time, median, 16% and 84% percentiles.

**Chart 10 – Evolution of variance decomposition at various horizons (fractions of variance explained by loan supply shocks)**



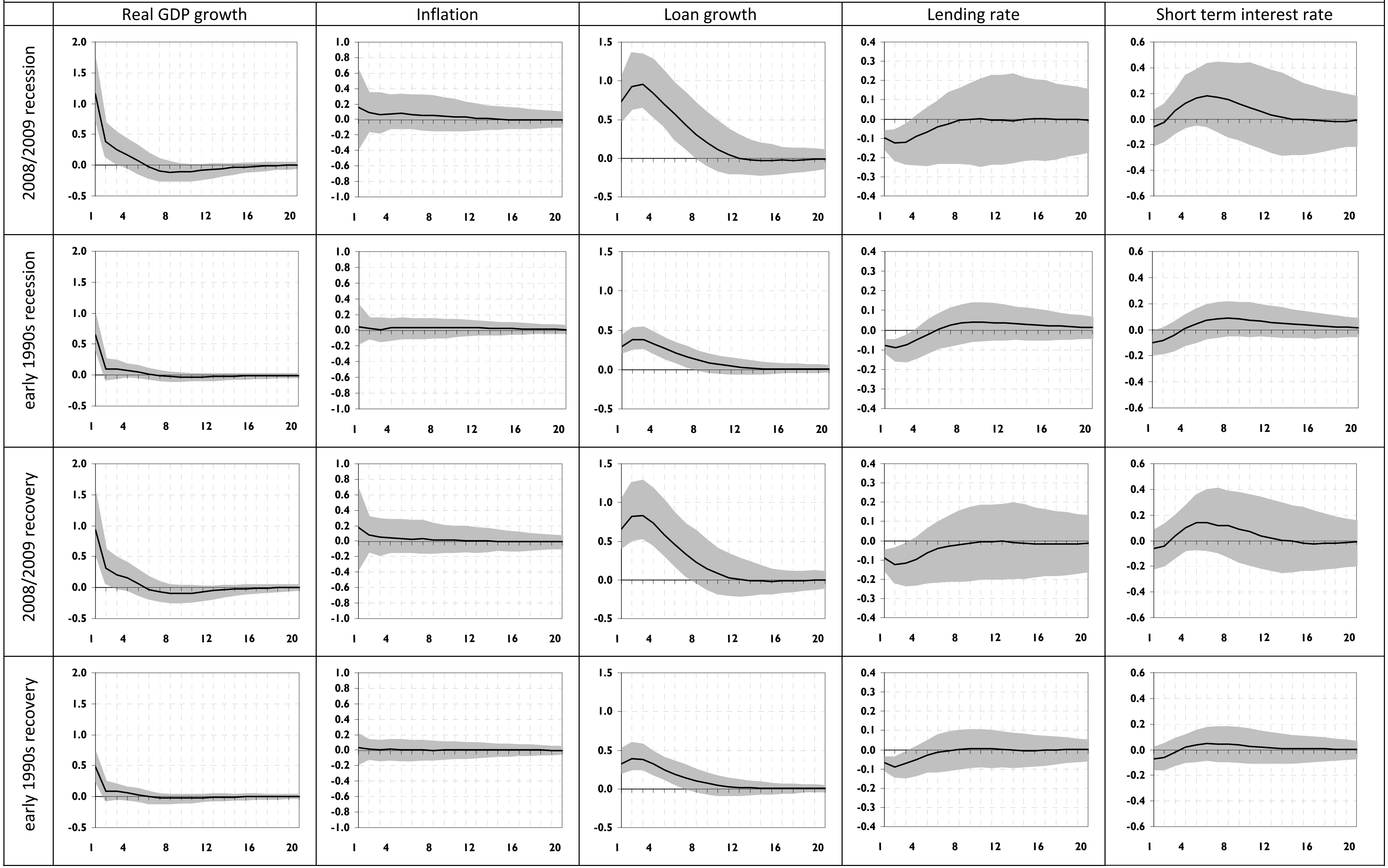

Note: Evolution of fractions of variances of the variables explained by loan supply shocks at specific horizons over time, median.

**Chart 11 – Counterfactual: evolution of the variables in the absence of loan supply shocks**



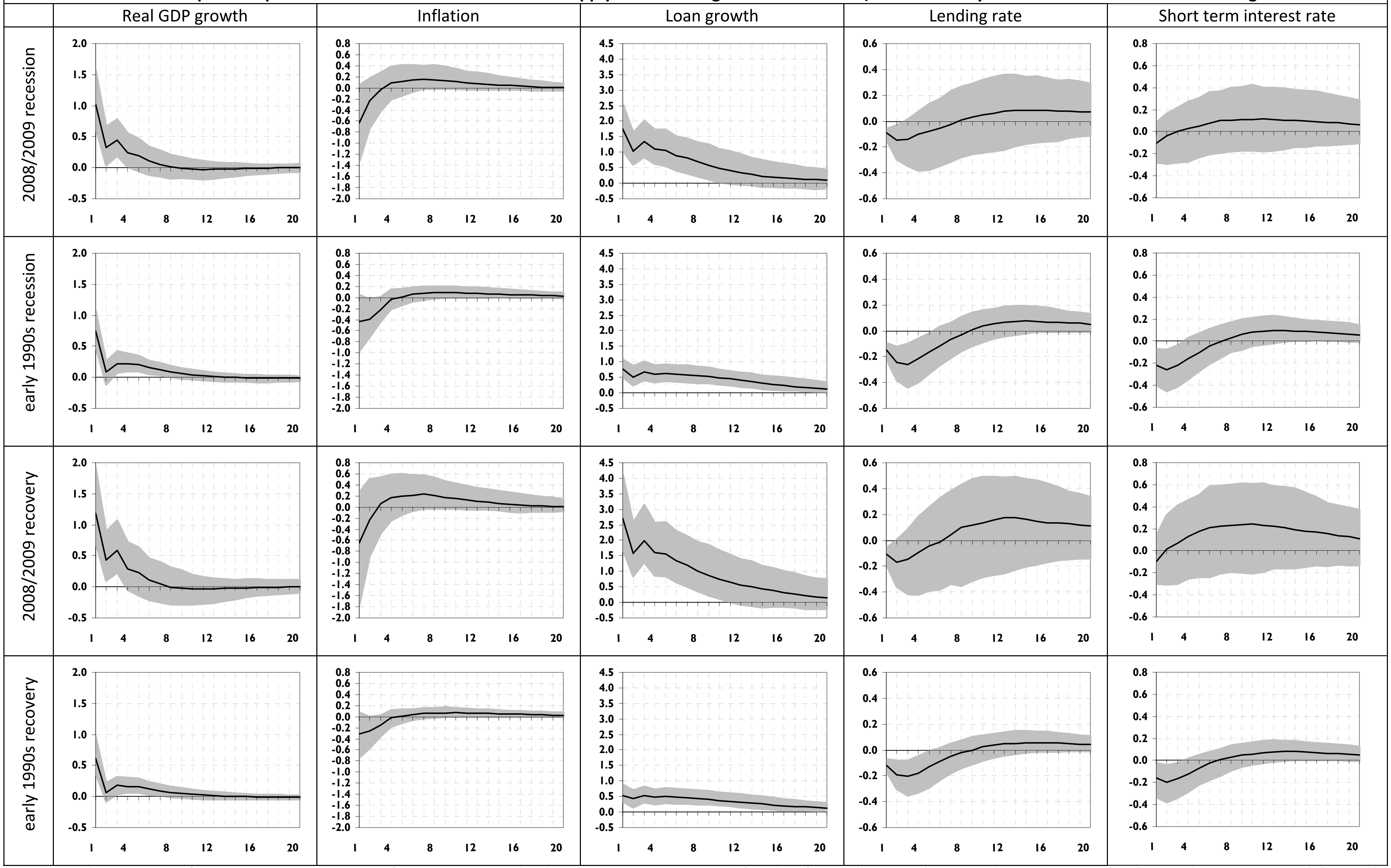

Note: Counterfactual exercises: evolution of variables in the absence of loan supply shocks.

**Chart 12 - Impulse response functions of all variables to loan supply shocks during and after the 2008/2009 and early 1990s recessions in the euro area**



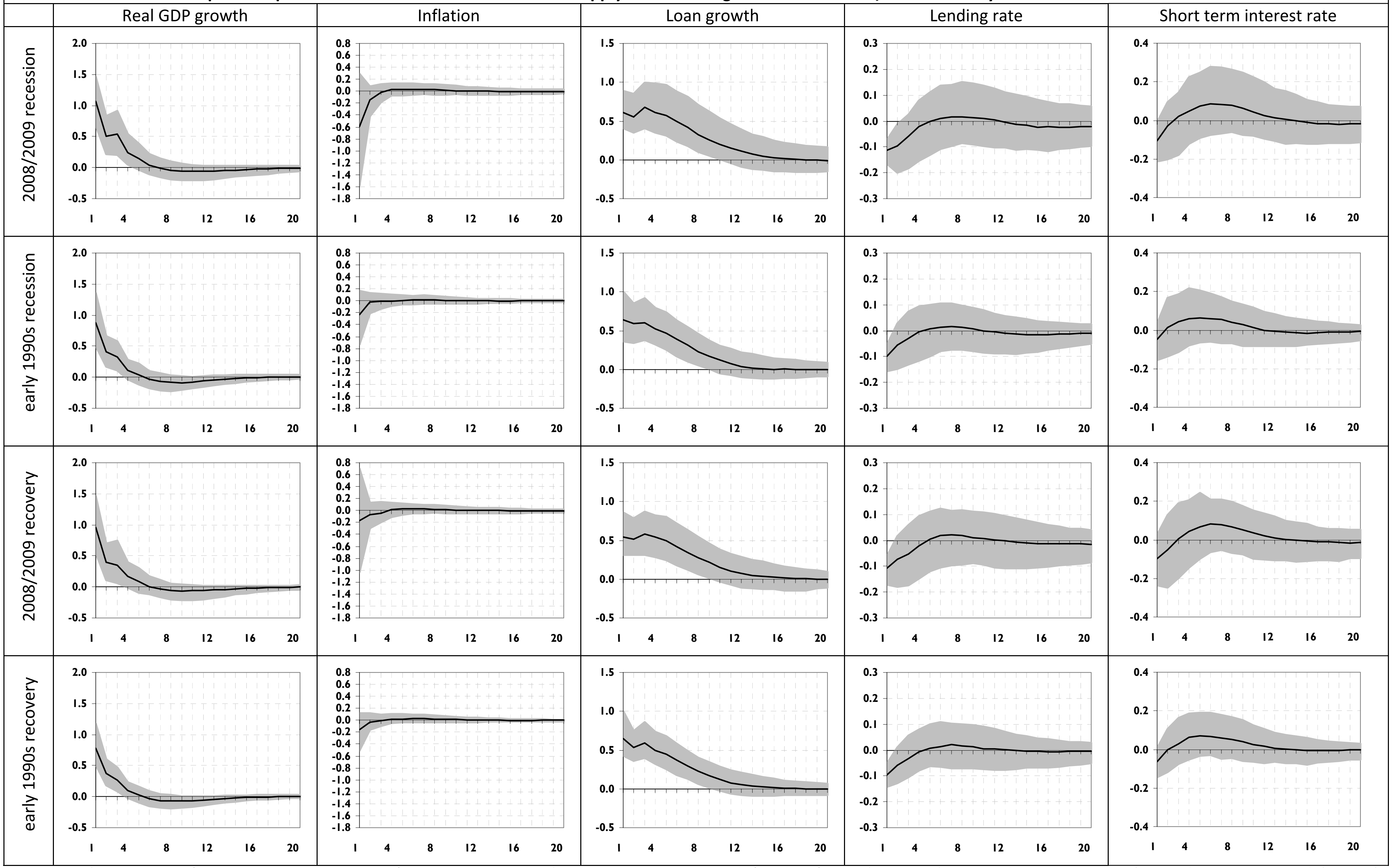

Note: Impulse response functions averages in specific recessions and subsequent recoveries as defined in first column in the Euro Area. Line is the median, grey area delimits the space between the 16% and 84% percentiles. Recessions as identified by the CEPR, recoveries as first four quarters after troughs.

**Chart 13 - Impulse response functions of all variables to loan supply shocks during and after the 2008/2009 and early 1990s recessions in the United Kingdom**



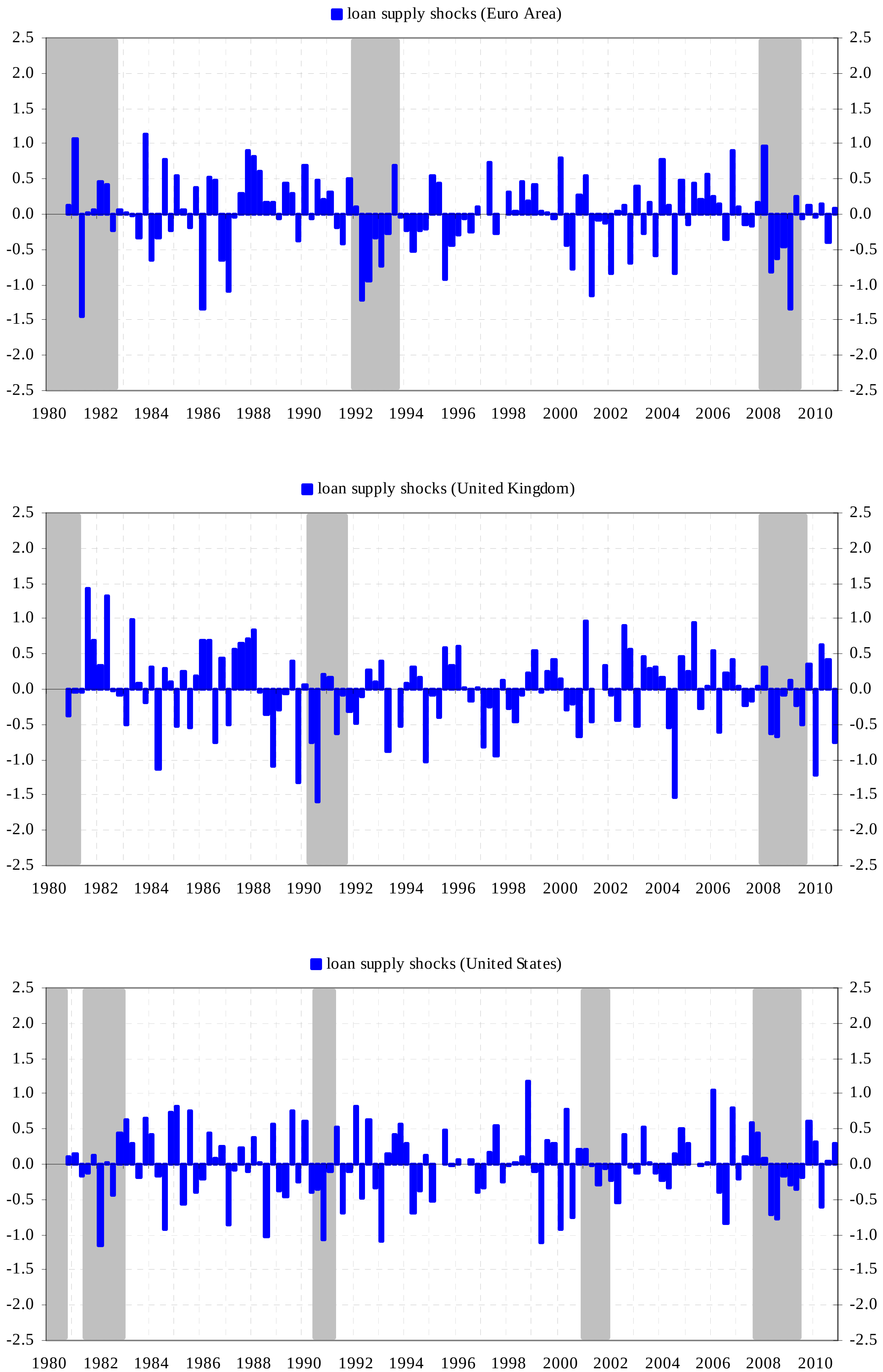

Note: Impulse response functions averages in specific recessions and subsequent recoveries as defined in first column in the United Kingdom. Line is the median, grey area delimits the space between the 16% and 84% percentiles. Recessions as identified by Bank of England, recoveries as first four quarters after troughs.

**Chart 14 - Impulse response functions of all variables to loan supply shocks during and after the 2008/2009 and early 1990s recessions in the United States**



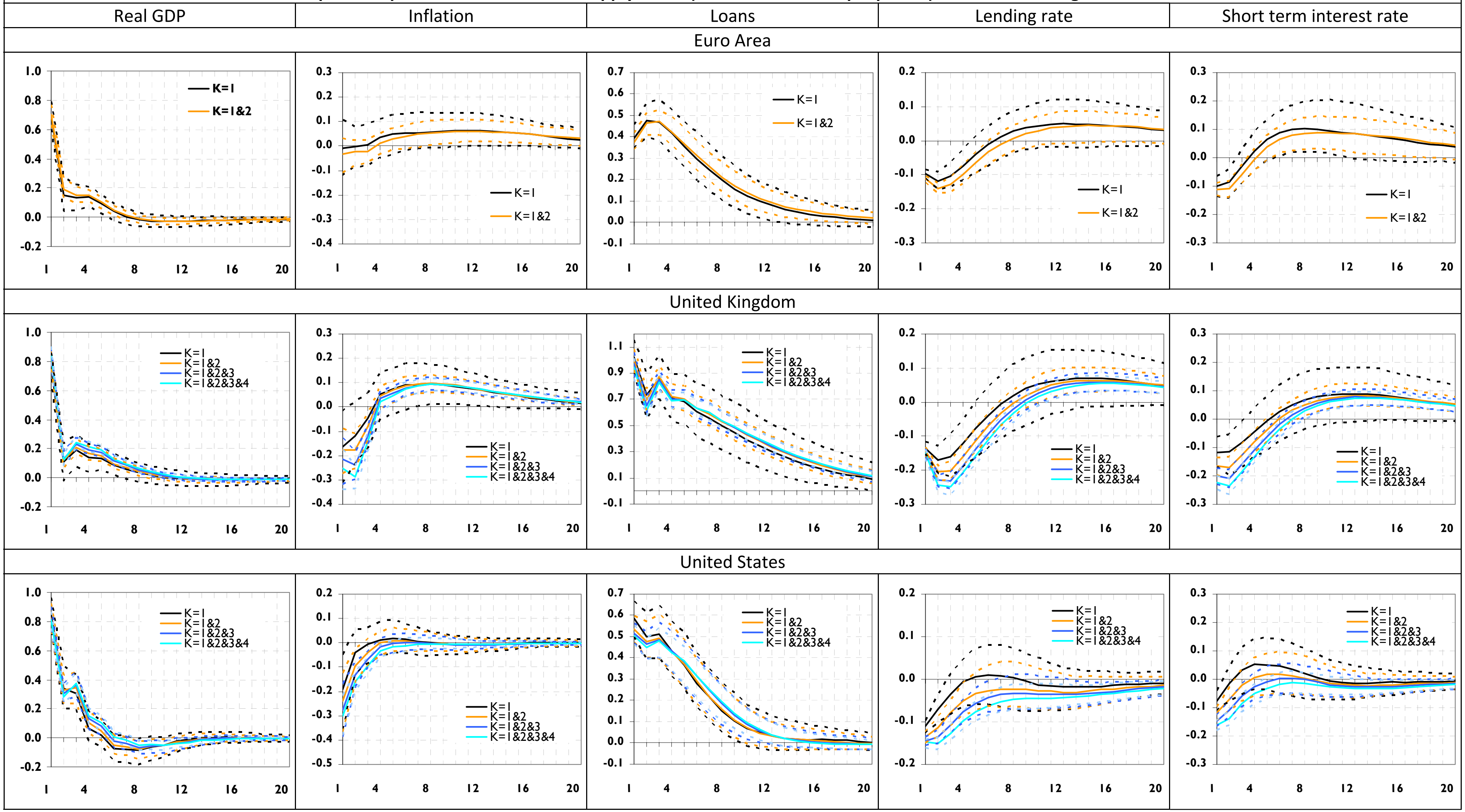

Note: Impulse response functions averages in specific recessions and subsequent recoveries as defined in first column in the United States. Line is the median, grey area delimits the space between the 16% and 84% percentiles. Recessions as identified by the NBER, recoveries as first four quarters after troughs.

**Chart 15 – Series of structural loan supply shocks**



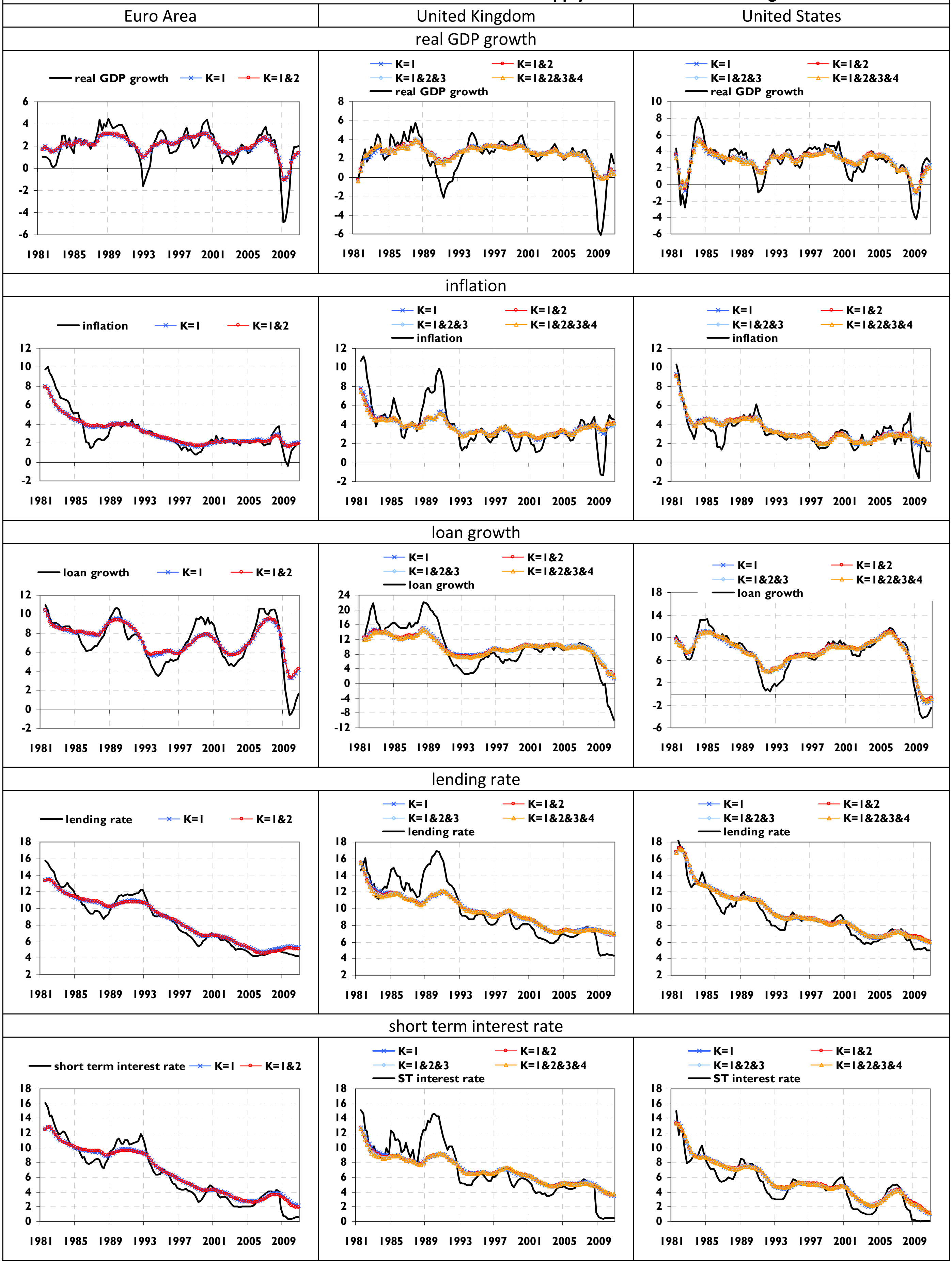

Note: Shaded areas delimit recession periods, as identified by the CEPR for the Euro Area, by the Bank of England for the United Kingdom and by the NBER for the United States.

**Chart 16 - Impulse response functions to loan supply shock (median whole sample period) for alternative sign restriction horizons**



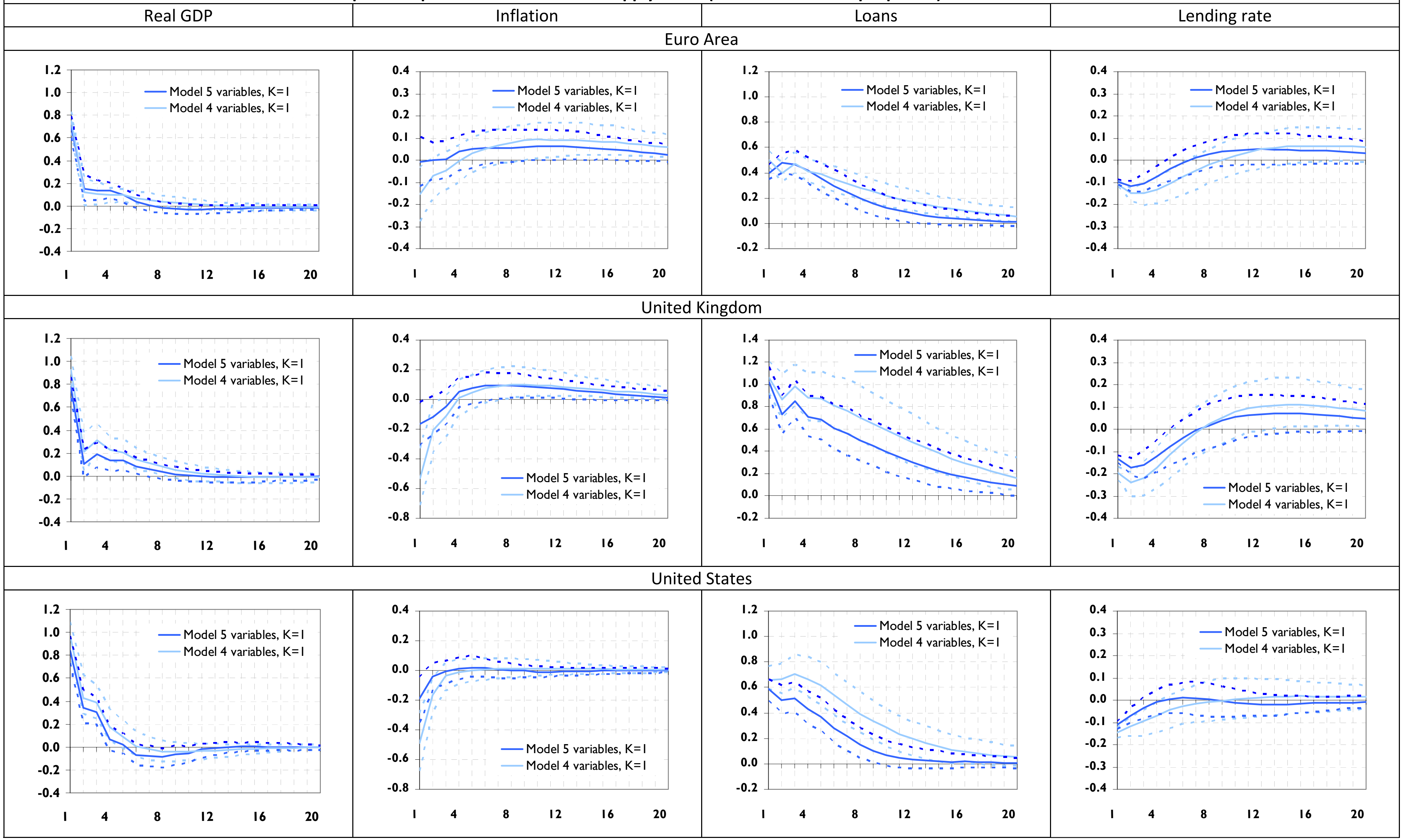

Note: Averages of impulse response functions over time. Line is the median, grey are delimits the space between the 16% and 84% percentiles. "K" is the number of periods over which the sign restrictions are imposed. K=1 refers to restrictions imposed only on impact. For the Euro Area results obtained only for K=1 and K=1&2.

**Chart 17 – Counterfactual: variables evolution in the absence of loan supply shocks for alternative sign restriction horizons**



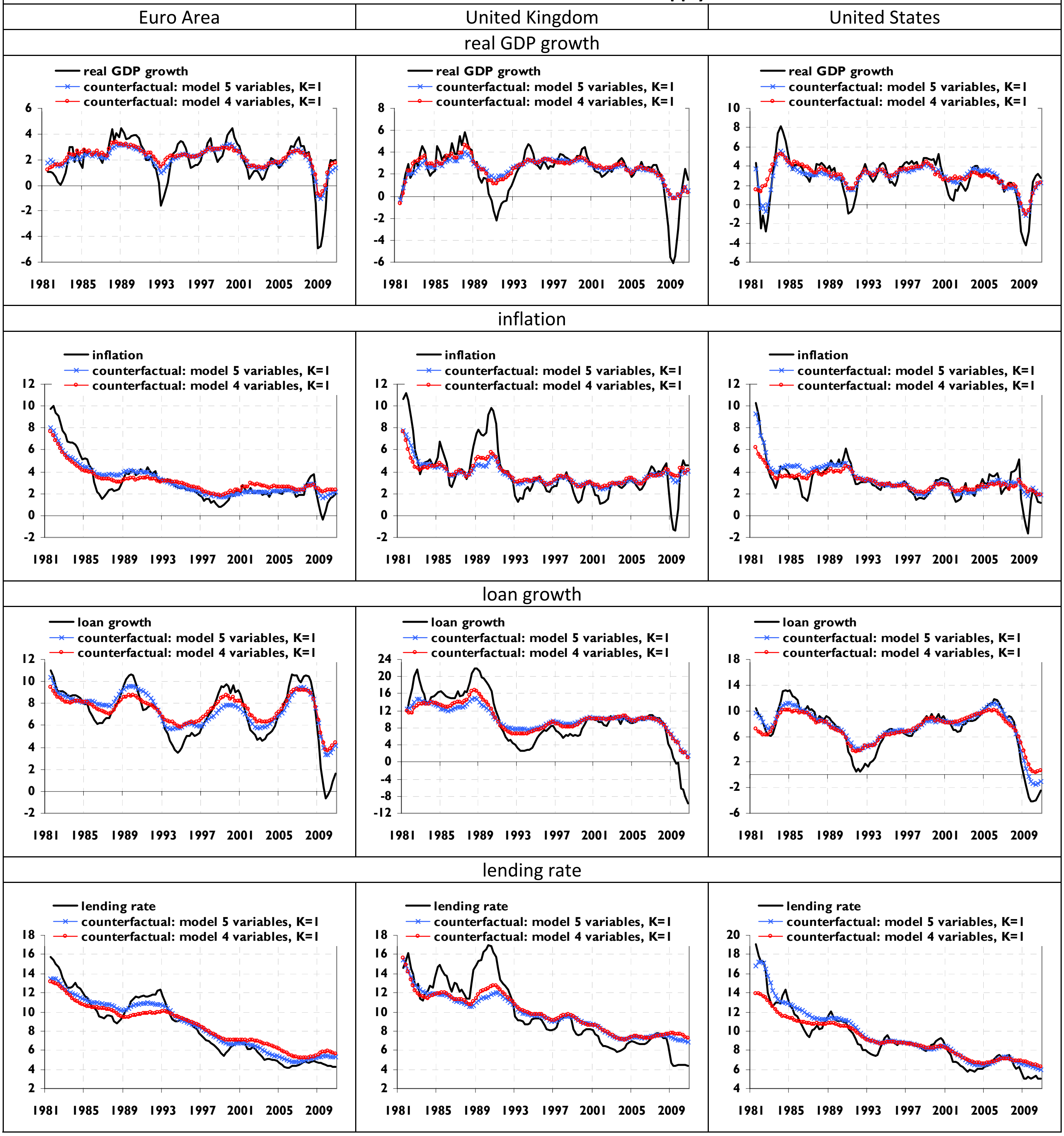

Note: Counterfactual exercises: evolution of variables in the absence of loan supply shocks. "K" is the number of periods over which the sign restrictions are imposed. K=1 refers to restrictions imposed only on impact. For the Euro Area results obtained only for K=1 and K=1&2.

**Chart 18 - Impulse response functions to loan supply shock (median whole sample period) for alternative model sizes**




Note: Averages of impulse response functions over time. Line is the median, grey are delimits the space between the 16% and 84% percentiles. Model with 5 variables includes real GDP growth, inflation, non-financial private sector loan growth, the composite lending rate and the short term interest rate (baseline model). Model with 4 variables includes only the latter first four variables (i.e. the variables on which sign restrictions are imposed. "K" is the number of periods over which the sign restrictions are imposed. K=1 refers to restrictions imposed only on impact (baseline).

**Chart 19 – Counterfactual: variables evolution in the absence of loan supply shocks for alternative model sizes**




Note: Counterfactual exercises: evolution of variables in the absence of loan supply shocks. Model with 5 variables includes real GDP growth, inflation, non-financial private sector loan growth, the composite lending rate and the short term interest rate (baseline model). Model with 4 variables includes only the latter first four variables (i.e. the variables on which sign restrictions are imposed. "K" is the number of periods over which the sign restrictions are imposed. K=1 refers to restrictions imposed only on impact (baseline).