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ON THE INTERACTION BETWEEN MARKET AND CREDIT RISK: A FACTOR-AUGMENTED VECTOR AUTOREGRESSIVE (FAVAR) APPROACH

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Abstract

The aim of the paper is to understand the interaction between market and credit risk. Using a comprehensive set of Italian data, we apply a factor model to identify the common sources of risk driving fluctuations in the real and financial sectors. The common latent factors are then inserted in a VAR framework via a Factor Augmented Vector Autoregressive (FAVAR) approach to analyse the role of risk interactions with monetary policy shocks. We find that the impact of a restrictive monetary policy shock on credit risk is amplified when considering the feedback effect deriving from macroeconomic and equity market risk. Thus, neglecting dynamic interactions among risks may lead to biased estimates of the overall risk measure. The approach provides a framework for modelling macro and financial feedback dynamics, shedding some light on the complex interdependence between the financial sector and the real economy.

JEL Classification: C32, E44, G21.
Keywords: FAVAR approach, credit risk, market risk, factor model.

Contents

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1. Introduction[1]

In financial institutions, the calculation of a comprehensive risk measure requires an approach to aggregating several risk types that takes into account possible inter-dependencies (inter-risk correlation). So far, two different approaches have been developed in the literature: the *top-down approach*, where the marginal distributions of individual risks are derived separately and then aggregated through a variance covariance or copula approach; the *bottom-up approach*, building on models taking into common risk drivers and their potential interactions.

The issue of risk aggregation has become increasingly important also from a supervisory perspective. The recent literature has shown that when positions in a portfolio depend simultaneously on both market and credit driven factors (for instance, foreign currency loans) risks tend to amplify rather than diversify away.[2] The development of credit risk transfer instruments and the use of mark-to-market accounting for a wide variety of financial instruments have blurred the standard distinction between market risk and credit risk, raising questions about treating the two separately. For example, it has been argued that in many practical risk assessment situations the conventional distinction between banking and trading book – mainly due to accounting purposes – does not hold,[3] ultimately resulting in a wrong assessment of true portfolio risk (see Basel Committee, 2009).

This paper analyses the interaction between market and credit risk in the context of risk aggregation. Using a comprehensive set of Italian data for the period 1999-2006, we apply a factor model to identify the common sources of risk driving fluctuations in the real and financial sectors.[4] The basic assumption is that there exist few common forces driving macro-financial fluctuations. These common sources of risk, as identified by a factor model, are analysed in a VAR framework via a Factor Augmented Vector Autoregressive (FAVAR) approach[5] shedding some light on the role of risk interactions when studying the responses of key selected variables to a monetary policy

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[2] See Breuer et al., 2008.

[3] Think of a portfolio of loans compared with a portfolio of traded bonds. Both are exposed to credit risk, which depends on the creditworthiness of the borrower and bond issuers, and to market risk arising form an adverse movement of interest rates. The only difference is that in the first case the losses materialize at the loan maturity.

[4] The FAVAR approach is applied to a balanced panel of 99 quarterly time series over the period March 1991-September 2006. The dataset includes: macroeconomic risk drivers (such as real GDP growth, industrial production indexes, unit labour costs, productivity, new orders, household consumption, exchange-rate changes, inflation-rate changes); credit risk indicators (as measured by Italian corporate default rates, defined as the ratio of the number of new borrowers defaulting to the number of performing borrowers); market risk factors (such as Italian equity stock index returns and their realized volatilities, characteristics of the euro-area yield curve, price-earnings ratio of the Italian stock market index, equity-market risk premium, Fama and French factors); variables summarizing the world business cycle (oil price and S&P 500, as indicators of global conditions).

[5] See Bernanke, Boivin and Eliasz (2004, 2005).

shock. The paper is very close in spirit to the bottom-up approach to risk aggregation, in that it provides a framework for the dynamic interactions of several risk drivers underlying a portfolio. It allows for macro-financial feedback dynamics and provides some insight into the complex interdependence between the financial sector and the real economy.

To the best of our knowledge this is the first time that the FAVAR approach is used to study the interaction between market and credit risk. There are multiple reasons for applying the FAVAR in our context. As in monetary policy, where policy makers respond to the overall state of the economy by taking into account a large economic and financial information set,[6] it appears that in order to identify the "fundamental" sources of risk, analyses should be based on a wide range of macro-financial variables. The application of factor models allows us to extend the space spanned by the risk factors and to improve the understanding of underlying sources of banking risks.[7] The VAR framework allows us to analyse the transmission mechanisms of specific shocks within the financial sector and their interaction with the real economy.

The main results of the study are the following. First, in response to a positive shock in interest rates both market and credit risk increase, with the latter effect being amplified by a deterioration in macroeconomic conditions. Second, the impact of a restrictive monetary policy shock on credit risk is amplified when considering the feedback effect deriving from the reaction of equity markets to the same shock.

From a policy perspective, our findings confirm that an integrated risk approach is essential to capture the effective amount of risk exposure. Neglecting dynamic interactions when measuring aggregate risks may lead to biased estimates of the overall risk measure.

The rest of the paper is organized as follows. Section 2 describes the related literature. Section 3 presents the FAVAR approach and its main characteristics. Section 4 describes the application of the FAVAR to the Italian case and discusses the results. Section 5 analyses more in detail how credit and market risk interact. Section 6 draws the conclusions.

2. Related literature

Risk aggregation is an important issue for the computation of an overall risk measure. Two different approaches have been developed so far: the *top-down* or *risk silos* approach, where the marginal distributions of individual risks are aggregated through a variance covariance or a copula approach (Alexander and Pèzier, 2003; Rosenberg and Schuermann, 2006); and the *bottom-u*p or

[6] This is explicitly stated in the two-pillar strategy of the ECB.
[7] Recent work has shown that few observable risk factors do not seem to explain much of the variation in banks' risk exposures (Rosenberg and Shuermann 2006).

base-level approach, based on a full modelling of common risk drivers and their interaction (Dimakos and Aas, 2004).

The literature related to the risk silos approach has shown that in most cases computing an aggregated economic capital measure gives rise to diversification benefits. Alexander and Pèzier (2003) use a normal copula to link the marginal distributions of market- and credit-risk factors. They find that the overall economic capital estimate benefits from a negative correlation among risk factors. Similarly, Rosenberg and Schuermann (2006) adopt a copulas-based approach to marginal distributions of aggregate risk factors. They find that the additive approach overestimates risk by more than 40 per cent, while if joint normality is assumed, risk is underestimated by a similar amount.

More recent research, however, has shown that the interaction among different risk types may be non-linear (see Breuer et al., 2008; Kupiec, 2007). As the recent financial crisis has shown, risks may reinforce each other, giving rise to *compounding effects.* This means that computing an overall economic capital measure simply by adding up individual capital requirements, as derived by artificially splitting value changes into pure market and credit risk components, might lead to an underestimation of true risk. The risk silos approach relies on the possibility of assessing ex ante which risk factor each asset is exposed to, ignoring the fact that such assets may depend simultaneously on various risk factors. To the extent that it does not recognize interdependencies among different risk types and possible reinforcing effects, the risk silos approach may lead to a biased estimate of the overall risk exposure.[8]

The base-level approach to risk aggregation derives an overall measure of economic capital by jointly modelling the evolution of several risk drivers of banking portfolios. Dimakos and Aas (2004) develop a framework where the loss distribution of different risk types (credit, market, ownership and business risk) is derived with a non-linear function of risk-factor fluctuations, as described by a multivariate GARCH model with t-distributed innovations.

Our paper is related to the literature on the base-level approach to risk aggregation, in that it provides a consistent framework to account for possible interdependencies among several risk drivers. To this end, we present an application of a FAVAR (Factor-Augmented Vector Autoregressive) approach to risk interaction for aggregation purposes.

Factor models have become popular both in empirical macroeconomics and finance, since they allow information to be extracted from large cross-sectional datasets. Factor models have been combined later with a standard VAR framework to exploit a larger information set in order to study

[8] Think of the credit risk on foreign loans, which are also exposed to the evolution of a market-risk variable such as the exchange rate. The 2007 financial turmoil has demonstrated that a perfect separation between assets sensitive to just credit-risk factors and those sensitive to just market-risk factors is indeed artificial: the market price and the liquidity of complex assets collapsed due to the evolution of risk drivers (house prices and reimbursement of non-prime loans), affecting the value of the instruments (structured credit products) only in an indirect way.

the macroeconomic effects of monetary policy interventions (Bernanke and Boivin, 2003; Bernanke Boivin and Eliasz, 2005; Stock and Watson, 2002 and 2005).

The strength of a Factor-Augmented Vector Autoregressive model (the FAVAR approach) lies in the possibility of analysing the dynamic interaction among a large number of macroeconomic and financial time series through a small number of unobservable factors, while preserving flexibility and parsimony.[9] In empirical finance the FAVAR approach has been used to analyse the interaction between financial markets and the real economy (Ludvigson and Ng, 2007 and 2009), to study the dynamics of the yield curve,[10] or to discover the predictive information content of credit-market spreads for future economic activity (Gilchrist, Yankov and Zakrajsek, 2009).

To the best of our knowledge this is the first time that a FAVAR model has been used for risk assessment and aggregation purposes. In this respect, our analysis improves other studies that have applied a multivariate GARCH framework and whose main limitation is the small number of variables that can be analysed simultaneously.

An alternative econometric framework that has been used in risk aggregation applications within the base-level approach is the GVAR approach by Pesaran et al (2006)[11], which has also been applied to the analysis of the interaction among real and financial variables (Pesaran et al., 2008). Unlike our framework, the GVAR model takes into consideration economic and financial interdependences across countries.

3. Dynamic factor models in a VAR framework: the FAVAR approach

The Factor Augmented Vector Autoregressive (FAVAR) approach, developed by Bernanke, Boivin and Eliasz (2005) consists of two steps. In the first step, few unobservable factors are extracted from large cross-sectional panel data (as in Stock and Watson, 2002). In the second step, these common latent factors are inserted in a VAR framework to derive the impulse response functions (IRF) of the original variables in the dataset to specific shocks, while taking into account the correlation of the system through its factorial structure.

Let Y_t be a M x 1 vector of observable variables driving the main dynamics of the economy. The conventional approach involves estimating a VAR (or other multivariate time series models)

[9] The main criticism of small-scale VARs is that they are unlikely to cover the vast information set available to policy makers and market participants, leading to biased inference. In addition, the choice of a specific data series as a single proxy for several economic or financial phenomena (e.g. industrial production for economic activity, consumer price index for the price level, equity indexes for market information) can be arbitrary and lead to omitted variable or measurement errors.

[10] In macro-term structure models, such as Monch (2008), yields are driven by expectations about future short-term interest rates, future inflation and risk premia; therefore, information on macroeconomic shocks has explanatory power also for the yield curve and thus for a driver of market risk.

[11] The GVAR is a global VAR model, composed of individual country VEC models in which the economic interdependence between countries are entered via trade-weighted foreign variables, treated as weakly exogenous.

using Y_t alone. However, when the number of variables of interest is large, it can be assumed that additional information, not fully captured by Y_t, may be relevant to modelling the dynamics in the system. It can also be assumed that the information can be summarized by a K x 1 vector of unobserved factors, F_t, where K is "small" compared with the original number of variables. More precisely, the assumption is that the dynamics in the economy can be represented by the following VAR (transition) equation:

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + v_t \qquad v_t \sim N(0, \Sigma) \tag{1}$$

where $\Phi(L)$ is a conformable lag polynomial of finite order d, which may contain a priori restrictions, as in the structural VAR literature. The error term v_t has mean zero and covariance matrix $\sum = E[v_t . v_t']$. Equation (1) is a VAR in (F_t, Y_t). This system reduces to a standard VAR in Y_t if the terms of $\Phi(L)$ that relate Y_t to F_{t-1} are all zero; otherwise, equation (1) expresses a *Factor-Augmented Vector Autoregression,* or FAVAR.[12]

Equation (1) cannot be estimated directly because the factors F_t are unobservable. However, it is possible to infer something about the factors from a wide set of observable variables (typically, a variety of economic and financial time series). More specifically, it can be assumed that the informational time series X_t are related to the unobservable factors F_t and the observed variables Y_t by an observation equation of the form:

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t \tag{2}$$

where Λ^f is an N x K matrix of factor loadings and e_t is a N x 1 vector of idiosyncratic measurement errors assumed to display some cross-correlation, that must vanish as N goes to infinity.[13] The implication of equation (2) that X_t depends only on the current and not the lagged values of the factors is not restrictive, as F_t can be interpreted as including arbitrary lags of the fundamental factors. The idea is that both the observable variables Y_t and the unobservable factors F_t (which in general can be correlated) represent common forces driving the dynamics of informational variables X_t where X_t is assumed to be large.[14]

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[12] Note that, if the true system is a FAVAR, estimation of (1) as a standard VAR system in Yt – with the factors omitted – will in general lead to biased estimates of the VAR coefficients and related quantities of interest, such as impulse response functions. Moreover, since the FAVAR model nests standard VAR analyses, estimation of equation (1) provides a way of assessing the marginal contribution of the additional information contained in F_t.

[13] Error terms e_t are mean zero and can be assumed either normal and uncorrelated (allowing for estimation by maximum likelihood methods) or weakly serially correlated with cross-section dependence, leading to estimation via quasi-maximum likelihood methods as in *approximate* factor models (see Bai and Ng, 2002).

[14] In particular, N may be greater than T (the number of time periods) and much greater than the number of factors and observed variables in the FAVAR system (K + M << N).

System (1) - (2) is estimated through a two-step approach where, first, the unobservable static factors are estimated with the first $K+M$ principal components of X_t[15]. The latent factors are identified by imposing the Watson normalization, which refers to the cross-section dimension.[16] The number of factors is determined according to the panel information criteria IC_1 and IC_2 proposed by Bai and Ng (2002).[17] The factors are then plugged into the transition equation of the FAVAR along with the observable risk factor Y_t to estimate the system and derive IRFs.

In a FAVAR, the dependence of the unobserved factors on the observable factor Y_t needs to be removed. To do this, we apply the methodology followed by Bernanke at al. (2005). First, all variables in the original dataset are classified into two groups: slow-moving variables, assumed not to respond contemporaneously to changes in the observable risk factor (in our application, the short-term interest rate) and fast-moving variables (see Table 1). Second, from the subset of slow-moving variables the factors F^*_t are extracted in order to run the following regression:

$$\hat{F}_t = b_f \hat{F}_t^* + b_y Y_t + e_t \qquad (3)$$

where $\hat{F}_t$ are the first $K+M$ principal components of X_t. The unobservable factors are then derived as:

$$\hat{F}_t - \hat{b}_y \; Y_t \qquad (4)$$

and included in the FAVAR system together with the policy variable. The FAVAR is estimated using a standard recursive assumption where all factors entering in (2) respond with lags to a change in the short-term interest rate ordered last in the VAR system.[18] The order of the VAR system is set to $p=1$, a lag length chosen according to the Hannan-Quinn and Schwarz information criteria. The assumption according to which the latent factors $\hat{F}_t$ do not respond contemporaneously to the observable variable(s) Y_t seems plausible since such latent factors mainly reflect the slow-moving component of the original dataset as a consequence of the methodology applied to remove their dependence on the observable variable(s) Y_t.

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[15] The latent factors Ft are estimated using asymptotic principal components. As shown in Stock and Watson (2002), when N is large and the number of principal components used is at least as large as the true number of factors, the principal components consistently recover the space spanned by both Ft and Yt.

[16] The Watson normalization is given by $(\Lambda'\Lambda)/N=I$ which implies $\hat{\Lambda} = \sqrt{N}\hat{Y}$ where $\hat{Y}$ are the eigenvectors corresponding to the K largest eigenvalues of the NxN matrix X'X, sorted in descending order. The common factors are, therefore, estimated as the eigenvectors corresponding to the *K* largest eigenvalues of the variance-covariance matrix *XX'*.

[17] The criteria proposed by Bai and Ng (2002) differ from the conventional C_p and information criteria used in time series analysis in that the penalty function $g(N;T)$ is a function of both N and T.

[18] Other identification schemes (e.g. long-run restrictions, as in Blanchard and Quah, 1989, or structural VAR procedures as in Bernanke and Mihov, 1998) can be implemented in the FAVAR framework. These would typically require, however, that some of the factors be identified as specific economic concepts. One way to achieve this would be by extracting the principal components from blocks of data corresponding to different dimensions of the space spanned by the factors.

The impulse response functions (IRFs) are derived as follows:

$$\begin{bmatrix} \hat{F}_t \\ Y_t \end{bmatrix} = \hat{\delta}(L)\ \upsilon_t \tag{5}$$

where υ_t is the vector of structural innovations and $\hat{\delta}(L)$ is the matrix of polynomials in the lag operator computed as the inverse of the matrix of polynomials in L from the structural VAR obtained from the reduced form VAR estimation. Finally, from the estimates of the observation equation Λ^f and Λ^y we get the IRFs for each variable we are interested in:

$$\hat{X}_t = [\Lambda^f \Lambda^y]\hat{\delta}(L)\upsilon_t \tag{6}$$

The distinctive feature of the approach is that the IRFs reflect the factorial structure of the system and, therefore, the dynamic interaction among the underlying risk drivers, both observable and unobservable.

The FAVAR approach has some limitations in that data have to be transformed in order to induce stationarity and it is not clear how the transformation interacts with the autoregressive structure of data. In addition, factors estimated through principal components are difficult to interpret. However, taking into account all the relevant information in a consistent way, it is robust to misspecification, omitted variable and measurement errors (so that, for example, in monetary policy studies no price or exchange-rate puzzles are generated).

Finally, the two-step approach implies the presence of "generated regressors" in the second step.[19] To obtain accurate confidence intervals on the impulse response functions reported below, we implement a bootstrap procedure, based on Kilian (1998), which accounts for the uncertainty in the factor estimation.

4. The latent risk factors: an application of the FAVAR approach to Italy

In our application to Italy, the FAVAR approach is used to summarize a large number of macroeconomic and financial time series by a small number of latent risk factors driving fluctuations in the Italian economic and financial sector. The methodology is used to identify the dynamic response of key selected variables to a monetary policy shock. X_t consists of 99 quarterly

[19] However, when N is large relative to T, the uncertainty in the factor estimates can be ignored: Bai and Ng (2006) show that pre-estimation of the factors does not affect the consistency of the second-stage parameter estimates or their standard errors.

time series[20] from March 1991 through September 2006 and covers (the description of the series and their transformation are reported in Table 1.):

- **macroeconomic variables,** such as real GDP growth, industrial production indexes, unit labour costs, productivity, new orders, household consumption, inflation rate. We also include the exchange rate between the home currency and the US dollar, to control for the terms of trade in international markets, and indicators of the monetary and credit conditions, such as various indicators of money supply, the spread between the lending rate to firms and the risk-free rate, and the difference between the average and the minimum rate on loans to firms;

- **credit risk indicators,** represented by the Italian default rates observed in eight industry sectors. The definition of default is based on the concept of "adjusted" bad loans and is defined as the ratio of the number of new borrowers defaulting to the number of performing borrowers at the beginning of the reference period.[21] We mapped the Credit Register industry code with the NACE rev. 1 classification, excluding exposures to the financial sector and to the public sector (sections J and L of the NACE classification). Table 2 reports the details of the classification and the mapping with the NACE codes;

- **market risk factors,** with a representative number of stock index returns observed in the Italian stock market and their realized volatilities, to capture uncertainty in the equity market.[22] The price-earnings ratio for the Italian stock market global index (PE) is also considered. As a proxy of investors' risk appetite we calculate the equity market risk premium as the difference between the inverse of the PE ratio and the redemption yield on the ten-year benchmark government bond. To account for the characteristics of the yield curve we consider its slope, computed as the difference between the ten-year government bond and the three-month Treasury bill rate, and real long-term interest-rate changes. To capture cross-sectional variation in market-risk premia (excess return predictability), we also

[20] The choice of what data to include in Xt is not trivial: while, in theory, more data are always better (see Stock and Watson, 2002), in practice that often means more of the same type of data, such as, for instance, more measures of real activity. Increasing N beyond a certain point is not always desirable (Boivin and Ng, 2006): when more 'noisy' series are added, the average common component will be smaller and/or the residual cross-correlation will eventually be larger than that warranted by theory.

[21] The Italian Central Credit Register (Centrale dei Rischi) is owned and managed by the Bank of Italy as a part of its Statistical Department. The Register records individual credit positions above 75,000 euros; bad loans are recorded whatever their amount. The "adjusted" bad loans used in the supervisory review process include: (i) loans to borrowers when the amount drawn exceeds the amount granted and the borrower is classified as defaulted (i.e. their loans are included in the bad loan category) by the only other reporting bank; (ii) loans to borrowers classified as defaulted by at least 2 banks whose exposure is over 10 per cent of the overall system exposure; (iii) loans to borrowers classified as defaulted by only one other bank if the exposure is either at least 70 per cent of the overall system exposure or the amount drawn exceeds by at least 10 per cent the amount granted.

[22] The realized volatility is calculated as the sum, over a three-month period, of squared returns on a weekly basis.

include the Fama and French factors, namely the momentum factor (UMD), the excess return on market (MKT), the "small-minus-big" (SMB) and "high-minus-low" (HML);[23]

- **world business cycle variables:** oil price and S&P 500, as indicators of global conditions.

All the series are transformed to induce stationarity; changes are computed on a one-year basis. Using the transformed dataset, we apply the approximate factor model (asymptotic principal component) in order to extract the underlying risk factors.

An important practical question is how many factors are needed to capture the necessary information to describe risk interactions properly. In our application, we run different test procedures for determining the number of risk factors. Applying the Bai and Ng (2002) criteria, the main driving forces in the Italian economy are represented by the first four latent factors (Figure 1). Overall, they explain around 55 per cent of the total variation.

The interpretation of the underlying unobservable factors, generally not relevant for forecasting purposes, is of some interest for risk management purposes, since they give insights about the main risk drivers in an asset portfolio. Owing to the well-known rotational indeterminacy problem in factor analysis,[24] a structural interpretation of the factor is difficult. Nonetheless, we carry out an extensive search on the dataset in order to give the underlying risk drivers a plausible interpretation. To gain some understanding of the economic and financial information captured by the factors, a useful method applied in practice is the one suggested by Stock and Watson (2002), who propose regressing the individual variables onto each factor in order to understand which of the original time series are more closely related to the latent factors.

By applying the method proposed by Stock and Watson, we look at the R-squared of the regressions of the 99 individual time series against each of the four latent factors. These R-squared are plotted as bar charts in Figures 2-5, with one chart for each factor. The first factor, accounting for 20 per cent of total variation, loads primarily on equity returns. We call it as the **equity-risk driver**. The second factor, explaining 19 per cent of variation, correlates with real activity variables. We refer to it as the **macroeconomic-risk driver**. The third factor, accounting for 11 per cent of total variation, loads on volatilities (**volatility-risk driver**). Finally, the fourth factor (7 per cent of total variation) loads on default rates (**credit-risk driver**).

[23] These factors are available from Kenneth French's web page. UMD (Up Minus Down) is created from portfolios, formed monthly, that are the intersections of two portfolios formed on size (market equity) and three portfolios formed on prior (2-12 month) return; it is the average return on the two high prior-return portfolios minus the average return on the two low prior-return portfolios. SMB is the difference between the returns on small and big stock portfolios with the same weighted-average book-to-market equity. HML is the difference between returns on high and low book-value/market-value portfolios with the same weighted-average size. Further details on these variables can be found in Fama and French (1993).

[24] Factors are only identifiable up to a rotation matrix: a potentially infinite number of linear rotations of the factors can be found, implying different sets of factor loadings (with different signs).

These latent factors, together with the short-term interest rate that we assume to be the observable risk driver related to monetary conditions (see the observation equation in the FAVAR model), represent the common sources of risk in the Italian economic and financial sector, potentially driving the credit and market risk of a portfolio.

In the FAVAR specification we treat the short-term interest rate *Yt* (the Italy T-Bill auction gross three-month rate) as observable and the other underlying risk drivers as unobservable. As for identification, we adopt a standard recursive scheme with the innovation in short-term interest rate ordered last.

In choosing the lag length of the VAR, different information criteria are analysed (see Table 3). Hannan-Quinn and Schwarz information criteria provide evidence in favour of a VAR with one lag, while Akaike criteria support the choice of a model with four lags. The analysis of the system shows serially uncorrelated residuals for both models (see the last column of Table 4), therefore we select the more parsimonious one. To corroborate our choice we also analyse the normality of the residual of the VAR model with one lag. Table 4 shows that, overall, normality is achieved.[25] This specification is also consistent with previous studies on quarterly data (for Italy, see Marcucci and Quagliariello, 2008).

The exercise consists in analysing the dynamic interaction of the latent risk drivers and their pattern of co-movement in response to a shock on the interest rate (a one-standard-deviation move, corresponding to a 50-basis-point increase in short-term interest rate). This is done by means of the Impulse Response Functions (IRFs) of key selected variables (default rates, real activity measures, asset prices, price-earnings ratio). The IRFs derive from the factorial structure of the system and reflect the dynamic interaction among the underlying sources of risk.

Figures 6-7 display the impulse response functions (IRF) in standard deviation units, with their respective 90 per cent confidence bands, of the key variables. It should be noted that since we are using the two-step principal component approach, the estimates suffer from the problem of generated regressors. To obtain accurate confidence intervals on the IRF we follow Bernanke, Boivin and Eliasz (2005), who implement a bootstrap procedure based on Kilian (1998) that accounts for uncertainty in the factor estimation.[26] The figures trace the impact of the shock 16 quarters ahead.

We find that in response to a positive shock in short-term interests rate both market risk (as embedded in a *long* net position in equity or bonds) and credit risk increase, with the latter effect being amplified by a deterioration of the macroeconomic conditions. The worsening of macroeconomic conditions is evidenced by a decline in real activity measures, which occurs after

[25] Some problems of skewness and kurtosis are only detected for equations 1 and 2.
[26] Bai and Ng (2006) show that the issue of generated regressors can be ignored if both N and T are large and N is much larger than T.

one quarter and is re-absorbed in two years. Household consumption also declines and the exchange rate appreciates. As for prices, the inflation rate decreases. All the shocks vanish in two years. These results are also robust to different factorial structures, with factors varying from two to four (Figures 6a-6c).

As for <u>credit risk</u>, Italian corporate default rates increase, both in aggregate and for the different sectors: an increase in interest rates leads to higher financing costs for firms, with a higher probability of financial distress and default. This is consistent with the "financial instability hypothesis" (Minsky, 1982; Kindleberger, 1978): a high level of the short-term interest rate increases the burden for borrowers and their probability of default; this accentuates the financial fragility of the whole economy and the negative consequences of a recession.[27] The year-on-year change in quarterly corporate default rates increases to 0.66 per cent in response to a 50-basis-point increase in interest rates, more than seven times the standard deviation. The shock is reabsorbed in six quarters. The impact has a different size and persistence in the different economic sectors (Figure 8). "Manufacturing", "Trade, hotels and restaurants" and "Agriculture, hunting, forestry and fishing" are more "cyclical", in that they show large positive impacts; the other sectors are more idiosyncratic, reacting less to the shock. This evidence is consistent with Italy's productive structure, with its multitude of small businesses, often organized into chains, districts or business groups, for which specific risk can be more significant.[28]

As <u>for market risk</u>, a 50-basis-point increase in short-term interest rates leads to an instantaneous decline in equity returns; the impact is different across equity sectors, both in intensity and in the timing of shock absorption. The immediate effect is an increase in firms' financial costs and therefore lower profits in the future; moreover, given higher bond yields, investments in the bond market become relatively more appealing to investors. The price-earnings ratio of the Italian stock market index declines with the shock as well. The slope of the yield curve declines, since the shock on short-tem interest rates is greater and more rapid than the one on long-term interest rates, thereby reflecting the lower volatility of long-term rates. The spread also declines, reflecting the delay with which banking rates adjust to policy rates;[29] the spread

[27] Our result is in line the literature on the relationship between interest rate and observed default frequencies (for recent evidence for Italy see also Marcucci and Quagliariello, 2008, and for Sweeden Per Asber Sommar and Hovick Shahnazarian, 2009). Market-driven measures of *expected* default, such as expected default frequencies derived from Merton models or credit spreads, seem instead to show a *negative* relationship (an increase in rates reflect the expectation of a more benign environment in the future, and hence of positive profits for the firm and lower future difficulties; see Duffie et al., 2007).

[28] See also R. Fiori, A. Foglia and S. Iannotti (2007, 2009), who find that the correlation of default rates across corporate sectors is due only in part to systematic risk factors: default rate movements across sectors are mainly idiosyncratic and subject to contagion effects across sectors. Moreover, it has to be noted that the time series on *observed* default frequencies adopted in this study also reflects the credit relationship between banks and firms, which might be influenced as well by some specific characteristic of the firms belonging to different sectors, such as the importance of a certain sector for the domestic economy or of a certain firm for its bank. In other words, it is possible, in principle, for a certain sector to attract firms whose characteristics influence bank *behaviour* in readily recognizing their default. To the best of our knowledge, this aspect has not been explored in depth.

[29] See Gambacorta and Iannotti (2007).

adjustment is more rapid than the slope adjustment. Finally, the risk premium increases but not significantly so (as well as volatility). All the shocks vanish in about two years.

It is worth noting that the exchange rate appreciates. This is consistent with the capital inflow that follows when interest rates increase. This is also consistent with the response of the competitive index (not shown), which declines, indicating an increase in competitiveness, even if not significant at conventional values.

5. The role of interaction

Our second set of results deals with the role of the dynamic interaction among different risk drivers and shows the importance of a base-level approach to risk aggregation.

The possibly malign interaction among different risk drivers can amplify the effect of a given shock on specific variables: the final effect depends not only on the direct impact of the shock on each risk variable, but also on the feedback effect arising from the dynamic responses of all risk factors to the same shock.

In order to better understand the role performed by each underlying common factor, we simulate the VAR model in the five factors (the four latent factors plus the interest-rate shock) by sterilizing the effect of each factor, one at a time. More specifically, the estimated system of equations (1)-(2) can be written as follows:

$$\hat{X}_t = [\Lambda^f \Lambda^y] \begin{bmatrix} \mathrm{F_t} \\ \mathrm{Y_t} \end{bmatrix} + \nu_t \qquad (7)$$

$$\begin{bmatrix} \mathrm{F_t} \\ \mathrm{Y_t} \end{bmatrix} = \Phi(\mathrm{L})\Gamma^{-1}\Gamma e_t = \Theta(L)\varepsilon_t \qquad (8)$$

where ε_t are the structural shocks. The impulse response functions to a monetary policy shock of each variable in the original dataset are a linear combination of the risk factors' IRFs where the weighting coefficients are given by the estimated factor loadings in the observation equation (1). Those factor loadings represent the contribution of each risk factor's IRF to the overall IRFs of each variable in the original dataset X_t.

In this context, the role of each risk factor can be sterilized by setting its contribution to the overall IRF to zero. This allows us to see how the impulse response functions of key selected variables change when the restriction holds. Figure 8A – 8D report the impulse response functions of selected risk variables neutralizing, respectively, the role of equity-risk driver, the macroeconomic-risk driver, the volatility-risk driver and the credit-risk driver.

As for credit risk, the impact from a monetary policy shock on corporate default rates is strongly amplified by deterioration in macroeconomic conditions (see Figure 9). If, in the model simulation, we sterilize the role of the macroeconomic risk factor, the impact on default rates is reduced by around 20 percent four steps ahead; the maximum impact in terms of standard deviation units is 0.058 (two steps ahead) against 0.065 of the benchmark model (three steps ahead).

As for the interaction of credit and market risk, we show that the impact of a monetary policy shock on the aggregate default rate is almost halved if one disregards the feedback effect of the shock from the equity markets (0.035 three steps ahead as opposed to 0.065 of the benchmark model). Conversely, the volatility risk factor does not seem to play any role on the aggregate default rate's impulse response function.

Performing the same type of analysis on market variables, it emerges that the reaction of those variables to a monetary policy shock is mainly driven by the equity-risk factor. This evidence is probably due to the different time horizon over which different risk drivers play out their effects. Typically, the effect of an increase in interest rates on macroeconomic and credit risks tend to materialize over a longer time horizon than market and volatility risks.[30]

6. Conclusions

The aim of the paper is to analyse the interaction between market and credit risk and the dynamics of risk transmission channels between the real economy and the financial sector. To this end, we use a factor model to identify the main common forces driving fluctuations in the Italian economy, thereby parsimoniously exploiting a broad information set. The FAVAR approach is then applied to shed some light on the role played by risk interactions when studying the responses of key selected risk variables to a monetary policy shock.

Our methodology is linked to literature on the base-level approach to risk aggregation, in that it provides a framework for the joint modelling of common sources of risk; a distinctive feature is the explicit recognition of the interrelation between the financial sector and the real economy. To the best of our knowledge this is the first time that a FAVAR framework is used in the context of risk interaction and aggregation.

We apply the methodology to Italy, on a balanced panel of 99 macroeconomic and financial quarterly time series over the period March 1991-September 2006. Using asymptotic principal component analysis, four latent risk factors are extracted, which we interpret as the equity-risk driver, the macroeconomic-risk driver, the volatility-risk driver, the credit-risk driver. Overall, they explain 55 per cent of total variation. These, together with the short-term interest rate assumed to be

[30] Calculations are available from the authors upon request.

observable, represent the common sources of risk in the economic and financial sector, potentially driving the risk exposure of a portfolio.

The exercise consists in analysing the dynamic interaction of the latent risk factors in response to a 50-basis-point increase in short-term interest rates. This is done by means of the IRF of the main representative variables (default rates, real activity measures, asset prices, price-earnings ratio), since the latent factors are only identifiable up to a rotation matrix. The main results are the following: first, in response to a restrictive monetary policy shock both market and credit risk increase, with the latter effect being amplified by a deterioration of the macroeconomic conditions.

Second, we provide evidence of dynamic interactions between different risk types, thereby underlining the importance of a base-level approach for risk aggregation. If we neutralize in the model the role of the macroeconomic risk factor, the impact of the monetary policy shock on corporate default rates is less significant. The interaction of credit and market risk appears more evident when considering that the impact of a monetary policy shock on the aggregate default rate is almost halved if one disregards the feedback effect of the shock from the equity markets. For market risk variables, we find that the impact is mainly related to the equity-risk driver.

Our findings confirm that an integrated risk modelling approach accounting for the interaction between market and credit risk is essential to capture the effective amount of risk exposure. Neglecting these interactions when measuring aggregate risks may lead to biased estimates of the overall risk exposure.

Our research has also implications for the study of financial stability and the crisis transmission mechanisms. The procedure that we have developed can be used for scenario analysis: selecting the relevant shock (e.g. a real identified shock, or exchange-rate shock or global stock-market shock) it would be possible to analyse the channels through which such shocks are transmitted and quantify their impact on the variables of interest. It can also be used for the definition of internally consistent shocks affecting a large number of macro and financial variables.

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Tables and Figures

TABLE 1

Macroeconomic variables	Mnemonic	Transformation Code	Slow moving variables
IT industrial production index	ITIPTOT.G	2	yes
IT industrial production index - MANUFACTURING	ITIPMAN.G	2	yes
IT industrial production index - CONSUMER GOODS	ITIPCNGDG	2	yes
IT industrial production index - INVESTMENT GOODS	ITIPINVTG	2	yes
IT industrial production index - INTERMEDIATE GOODS	ITIPINTMG	2	yes
IT industrial production index - INDEX: ENERGY	ITIPENGYG	2	yes
IT industrial production index - CHEMICAL PRODUCTS & SYNTHETICFIBRES	ITIPCHEMG	2	yes
IT industrial production index - COKE MANUFACTURE & PETROLEUM REFINING	ITIPFUELG	2	yes
IT industrial production index - ELECTRICAL MACHINES & APPARATUS	ITIPEMACG	2	yes
IT industrial production index - ELECTRICITY, GAS & WATER VOLA	ITIPELGWG	2	yes
IT industrial production index - EXTRACTION OF MINERALS VOLA	ITIPMINGG	2	yes
IT industrial production index - FOOD, DRINK & TOBACCO VOLA	ITIPFOODG	2	yes
IT industrial production index - LEATHER PRODUCTS VOLA	ITIPLEATG	2	yes
IT industrial production index - MACHINES & MECHANICAL APPARATUS VOLA	ITIPMACHG	2	yes
IT industrial production index - MANUFACTURE OF FURNITURE VOLA	ITIPFURNG	2	yes
IT industrial production index - MEANS OF TRANSPORT VOLA	ITIPTRNSG	2	yes
IT industrial production index - METAL & METAL PRODUCTS VOLA	ITIPMETLG	2	yes
IT industrial production index - OTHER MANUFACTUING INCLUDING FURNITURE	ITIPOTHRG	2	yes
IT industrial production index - PAPER PRODUCTS, PRINTING & PUBLISHING VOLA	ITIPPAPRG	2	yes
IT industrial production index - RUBBER ITEMS & PLASTIC MATERIALS VOLA	ITIPRUBRG	2	yes
IT industrial production index - TEXTILE & CLOTHING VOLA	ITIPTEXTG	2	yes
IT industrial production index - WOOD & WOOD PRODUCTS VOLA	ITIPWOODG	2	yes
IT industrial production index - WORKING OF NON-METALLIC MINERALS VOLA	ITIPNMTLG	2	yes
IT Real GDP Growth	ITGDP...D	2	yes
IT Final Domestic Consumption: HOUSEHOLDS	ITCNPER.D	2	yes
IT Productivity - Industry excluding Construction	ITPRODVTE	2	yes
IT unit labour cost - Industry excluding Construction	ITLCOST.E	2	yes
IT New Orders	ITNEWORDE	2	yes
ITOCFOGPQ	ITOCFOGPQ	1	yes
Lending Rate - Risk Free Rate	SPREAD	1	no
Interbank Rate on 3-Month Deposits - Short Term Euro Repo Rate	LIQUID	1	no
Average rate on loans - minimun rate on loans to firms	SPREAD_FIRM	1	no
Maximum rate on loans to firms - Average rate on loans	SPREAD_FIRM_	1	no
IT Italian Lire TO US $ (MTH.AVG.)	ITXRUSD.	2	no
IT MONEY SUPPLY: M3 - Iitalian contribution to the EURO AREA	ITM3....A	2	no
IT MONEY SUPPLY: M1 - Iitalian contribution to the EURO AREA	ITM1....A	2	no
IT MONEY SUPPLY: M2 - Iitalian contribution to the EURO AREA	ITM2....A	2	no
Inflation Rate	ITCPANNEL	3	yes
Credit risk indicators	**Mnemonic**	**Transformation Code**	**Slow moving variables**
Corporate Sector default rate	Default Rate	4	yes
Sectoral default rate - Agriculture, hunting, forestry and fishing	S1	4	yes
Sectoral default rate - Mining and quarrying	S2	4	yes
Sectoral default rate - Manufacturing	S3	4	yes
Sectoral default rate - Electricity,gas and water supply	S4	4	yes
Sectoral default rate - Constructions	S5	4	yes
Sectoral default rate - Trade, hotels and restaurants	S6	4	yes
Sectoral default rate - Transport,storage and communication	S7	4	yes
Sectoral default rate - Other industries	S8	4	yes

Source: Bank of Italy and Datastream Thomson Reuters Financial . The transformation codes are 1= no transformation; 2=delta logarithm; 3= first differences; 4= delta logit transformation.

TABLE 1 – cont.

Market risk factors	Mnemonic	Transformation Code	Slow moving variables
ITALY- Stock Market index - PRICE INDEX	TOTMKIT	2	no
ITALY- Sectoral Stock Market index - Oil & Gas - PRICE INDEX	OILGSIT	2	no
ITALY- Sectoral Stock Market index - Chemicals - PRICE INDEX	CHMCLIT	2	no
ITALY- Sectoral Stock Market index - Basic Resource - PRICE INDEX	BRESRIT	2	no
ITALY- Sectoral Stock Market index - Con & Mat - PRICE INDEX	CNSTMIT	2	no
ITALY- Sectoral Stock Market index - Inds Gds & Svs - PRICE INDEX	INDGSIT	2	no
ITALY- Sectoral Stock Market index - Auto & Parts - PRICE INDEX	AUTMBIT	2	no
ITALY- Sectoral Stock Market index - Pers & H/H Gds - PRICE INDEX	PERHHIT	2	no
ITALY- Sectoral Stock Market index - Health Care - PRICE INDEX	HLTHCIT	2	no
ITALY- Sectoral Stock Market index - Retail - PRICE INDEX	RTAILIT	2	no
ITALY- Sectoral Stock Market index - Media - PRICE INDEX	MEDIAIT	2	no
ITALY- Sectoral Stock Market index - Travel & Leis - PRICE INDEX	TRLESIT	2	no
ITALY- Sectoral Stock Market index - Telecom - PRICE INDEX	TELCMIT	2	no
ITALY- Sectoral Stock Market index - Banks - PRICE INDEX	BANKSIT	2	no
ITALY- Sectoral Stock Market index - Insurance - PRICE INDEX	INSURIT	2	no
ITALY- Sectoral Stock Market index - Technology - PRICE INDEX	TECNOIT	2	no
ITALY- Sectoral Stock Market index - Financial Svs - PRICE INDEX	FINSVIT	2	no
ITALY- Sectoral Stock Market index - Utilities - PRICE INDEX	UTILSIT	2	no
ITALY- Stock Market index - REALIZED VOL	TOTMKITV	1	no
ITALY- Sectoral Stock Market index - Oil & Gas - 3-MONTH REALIZED VOL	OILGSITV	1	no
ITALY- Sectoral Stock Market index - Chemicals - 3-MONTH REALIZED VOL	CHMCLITV	1	no
ITALY- Sectoral Stock Market index - Basic Resource - 3-MONTH REALIZED VOL	BRESRITV	1	no
ITALY- Sectoral Stock Market index - Con & Mat - 3-MONTH REALIZED VOL	CNSTMITV	1	no
ITALY- Sectoral Stock Market index - Inds Gds & Svs - 3-MONTH REALIZED VOL	INDGSITV	1	no
ITALY- Sectoral Stock Market index - Auto & Parts - 3-MONTH REALIZED VOL	AUTMBITV	1	no
ITALY- Sectoral Stock Market index - Pers & H/H Gds - 3-MONTH REALIZED VOL	PERHHITV	1	no
ITALY- Sectoral Stock Market index - Health Care - 3-MONTH REALIZED VOL	HLTHCITV	1	no
ITALY- Sectoral Stock Market index - Retail - 3-MONTH REALIZED VOL	RTAILITV	1	no
ITALY- Sectoral Stock Market index - Media - 3-MONTH REALIZED VOL	MEDIAITV	1	no
ITALY- Sectoral Stock Market index - Travel & Leis - 3-MONTH REALIZED VOL	TRLESITV	1	no
ITALY- Sectoral Stock Market index - Telecom - 3-MONTH REALIZED VOL	TELCMITV	1	no
ITALY- Sectoral Stock Market index - Banks - 3-MONTH REALIZED VOL	BANKSITV	1	no
ITALY- Sectoral Stock Market index - Insurance - 3-MONTH REALIZED VOL	INSURITV	1	no
ITALY- Sectoral Stock Market index - Technology - 3-MONTH REALIZED VOL	TECNOITV	1	no
ITALY- Sectoral Stock Market index - Financial Svs - 3-MONTH REALIZED VOL	FINSVITV	1	no
ITALY- Sectoral Stock Market index - Utilities - 3-MONTH REALIZED VOL	UTILSITV	1	no
ITALY- Stock Market index - PRICE EARNING RATIO	TOTMKIT(PE)	1	no
ITALY T-Bill Auct. Gross 3 Month - Risk Free Rate	ITBT03G	3	no
Real Long Term Interest rate	IR real_long	3	no
Risk Premium	Risk premium	1	no
IT Treasury Bond Net Yield - IT T-Bill Auct.Gross 3 Month Rate	SLOPE	1	no
IT Fama French Factor: Mkt	Mkt	1	no
IT Fama French Factor: BE/ME High	BMHigh	1	no
IT Fama French Factor: BE/ME Low	BMLow	1	no
IT Fama French Factor: E/P High	EPHigh	1	no
IT Fama French Factor: E/P Low	EPLow	1	no
IT Fama French Factor: CE/ PHigh	CEPHigh	1	no
IT Fama French Factor: CE/ PLow	CEPLow	1	no
IT Fama French Factor: D/P High	DPHigh	1	no
IT Fama French Factor: D/P Low	DPLow	1	no
World business cycle variables	**Mnemonic**	**Transformation Code**	**Slow moving variables**
S&P 500 COMPOSITE - PRICE INDEX	S&PCOMP	2	no
Crude Oil-Brent Cur. Month FOB U$/BBL	OILBREN	2	no

Source: Bank of Italy and Datastream Thomson Reuters Financial . The transformation codes are 1= no transformation; 2=delta logarithm; 3= first differences; 4= delta logit transformation.

TABLE 2. Default rates: industry classification

ECONOMIC SECTORS	NACE rev.1
1- Agriculture, hunting, forestry and fishing	A+B
2 - Mining and quarrying	C
3 - Manufacturing	D
4 - Electricity,gas and water supply	E
5 - Construction	F
6 - Trade, hotels and restaurants	G+H
7 - Transport,storage and communication	I
8 - Other services	K+N+O

TABLE 3. Lag order Determination

Information criteria: AK=Akaike, SC=Schwarz and HQ=Hannan-Quinn. GODF=Godfrey portmanteau test for autocorrelation of order 4. The symbol * indicates the lag order selected by the criterion.

lag (h)	AK	HQ	SC	GODF p-value
1	-11.92	-11.52*	-10.87*	0.093
2	-11.93	-11.18	-9.99	0.002
3	-12.11	-11.02	-9.30	0.101
4	-11.75*	-10.31	-8.06	0.449

TABLE 4. JARQUE-BERA Normality Test

Equation	Skewness	p-value	Kurtosis	p-value	Skewness & Kurtosis	p-value (1)
1	0.663	0.415	1.535	0.215	2.199	0.333
2	0.000	0.992	13.055	0.000	13.055	0.001
3	0.153	0.696	1.448	0.229	1.601	0.449
4	9.496	0.002	0.137	0.711	9.633	0.008
5	3.698	0.054	0.034	0.854	3.732	0.155
system	7.935	0.160	3.995	0.550	11.930	0.290

(1) Normality is accepted when the p-value is larger than 5 per cent.

Figure 1

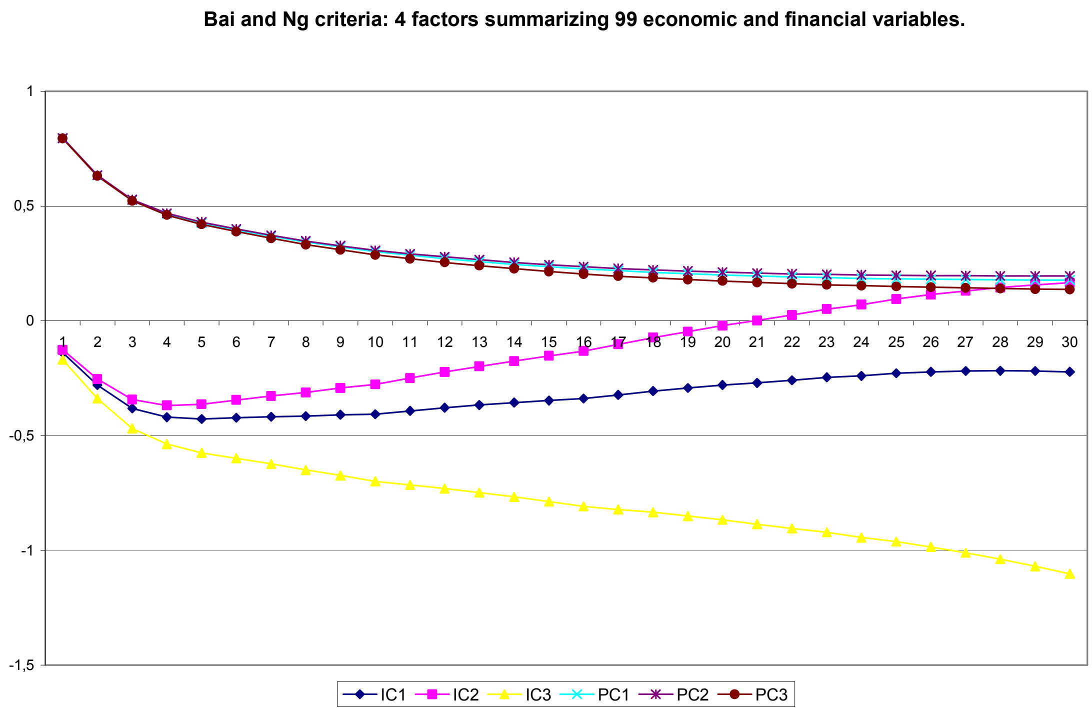

Bai and Ng criteria: 4 factors summarizing 99 economic and financial variables.
1
0,5
0
-0,5
-1
-1,5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
IC1
IC2
IC3
PC1
PC2
PC3

Figure 2

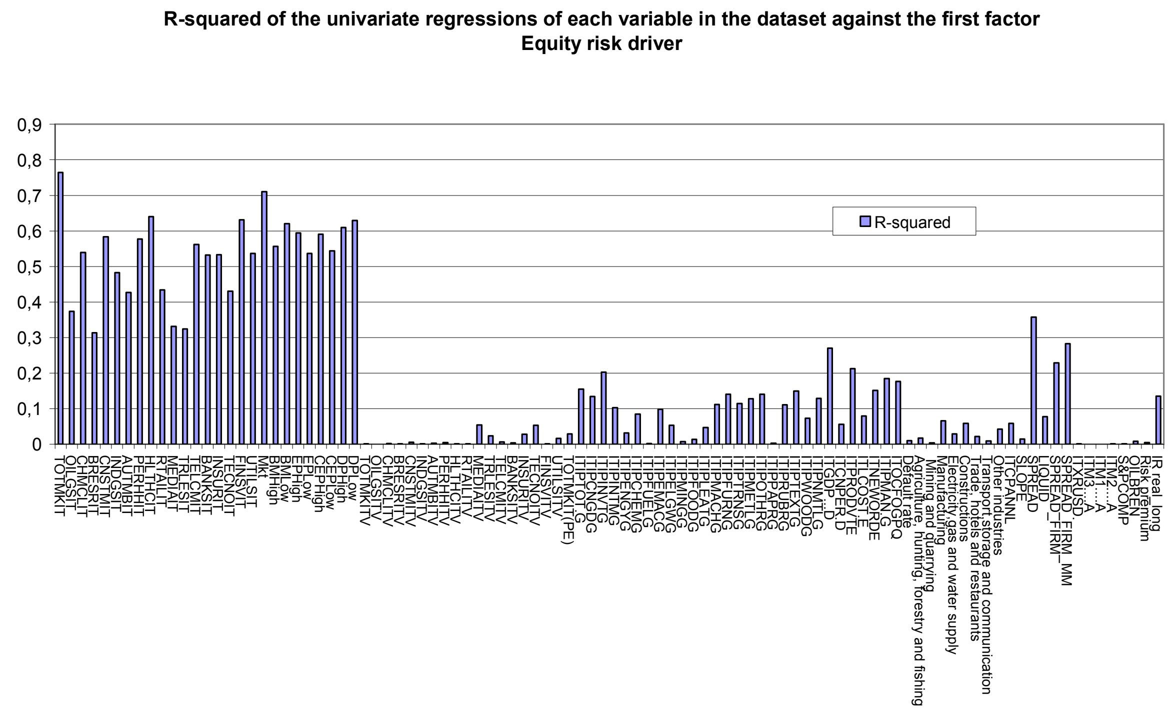


Figure 3

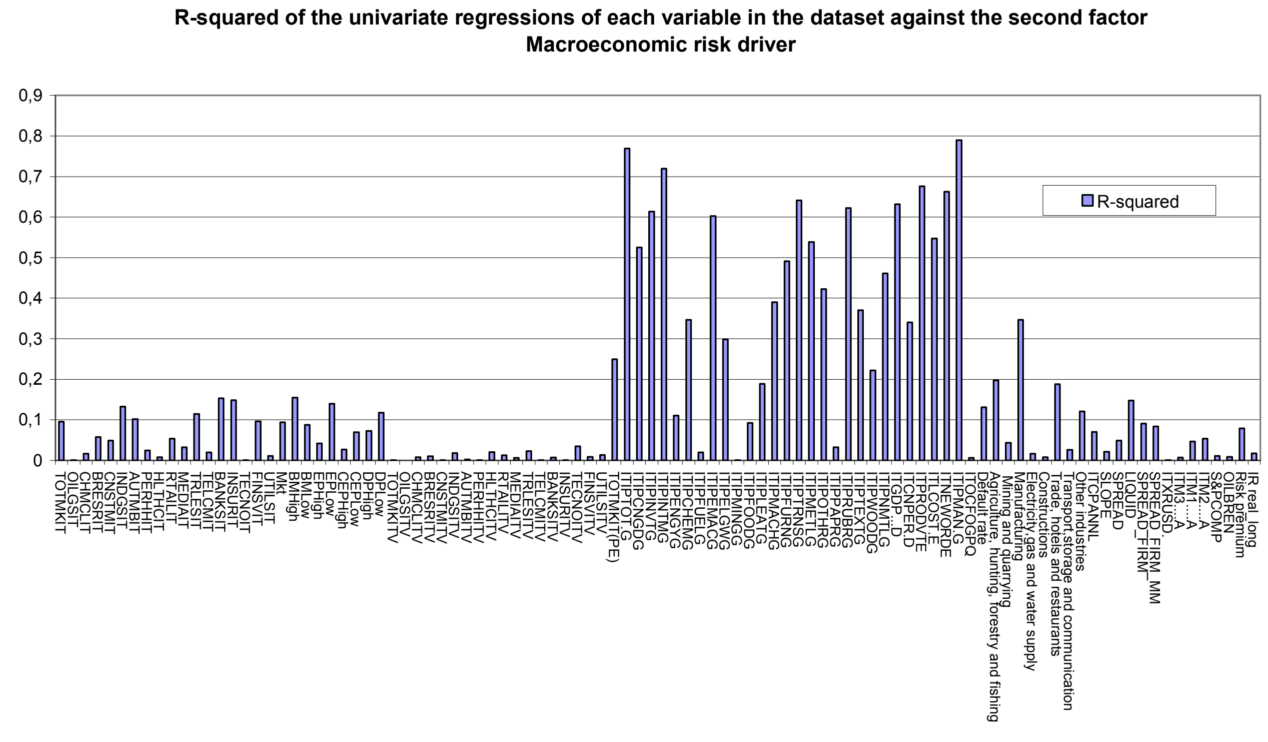


Figure 4

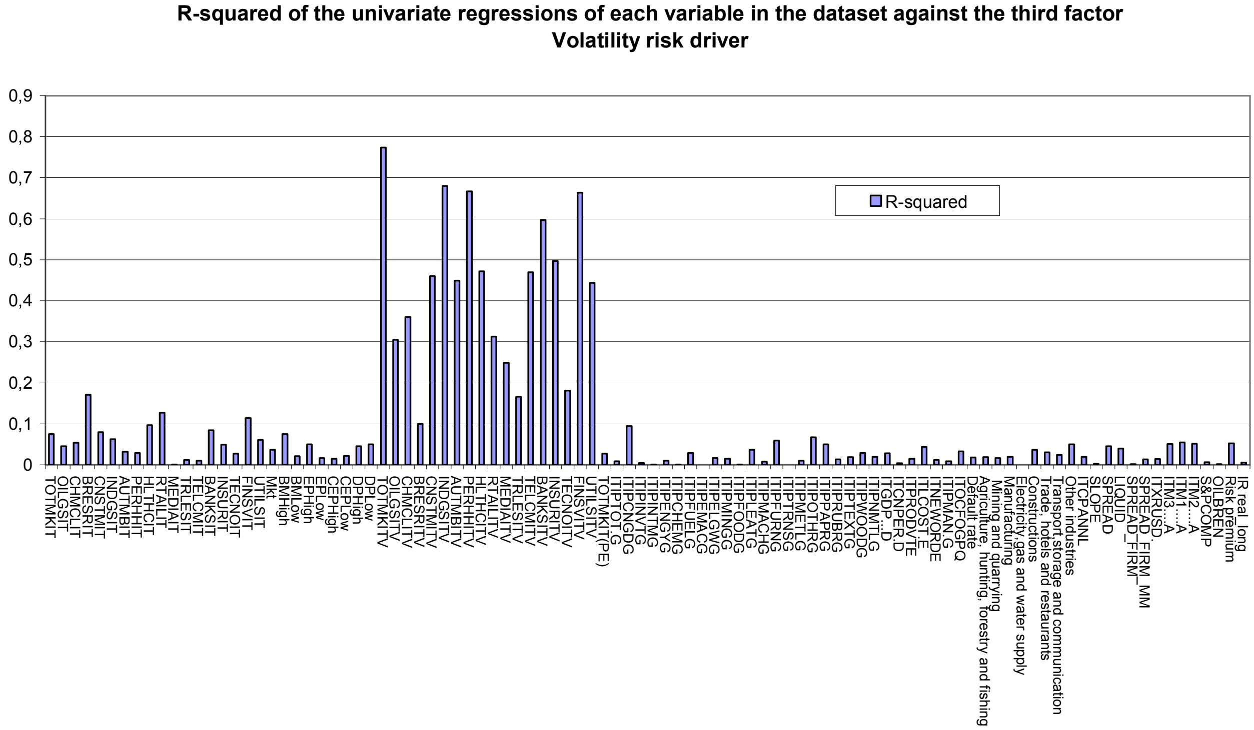


Figure 5

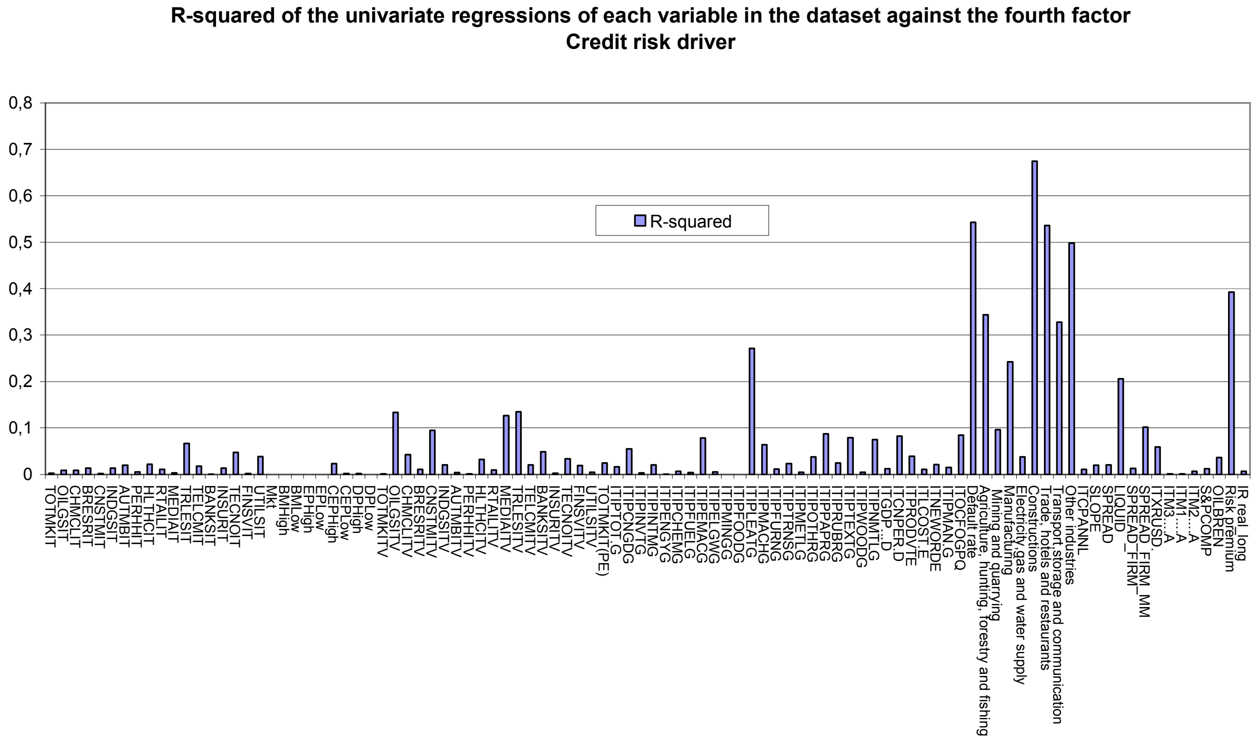
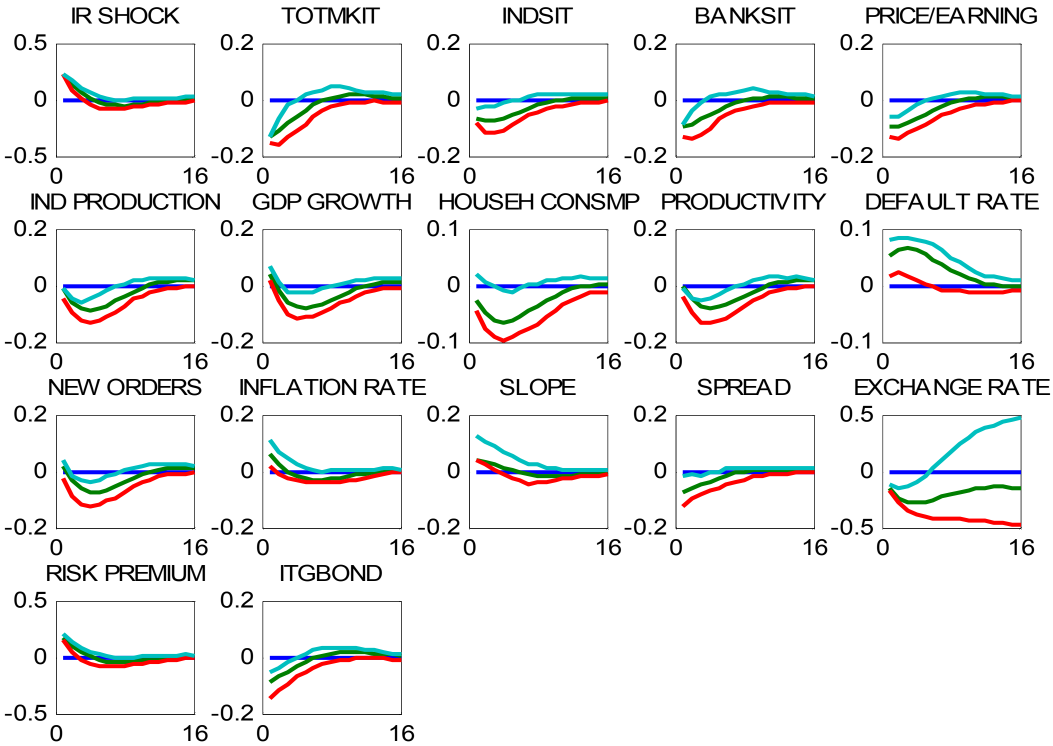
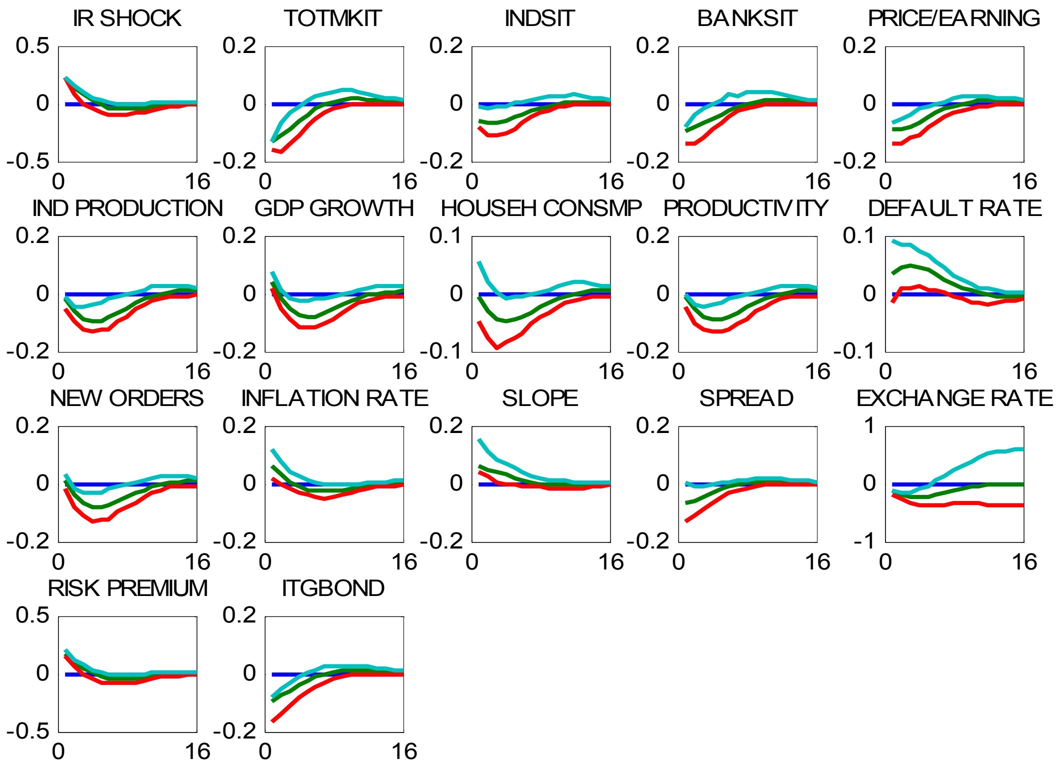


Figure 6a
IMPULSE RESPONSE FUNCTIONS (4 factors)
Benchmark model
Selected Macro and Financial Variables



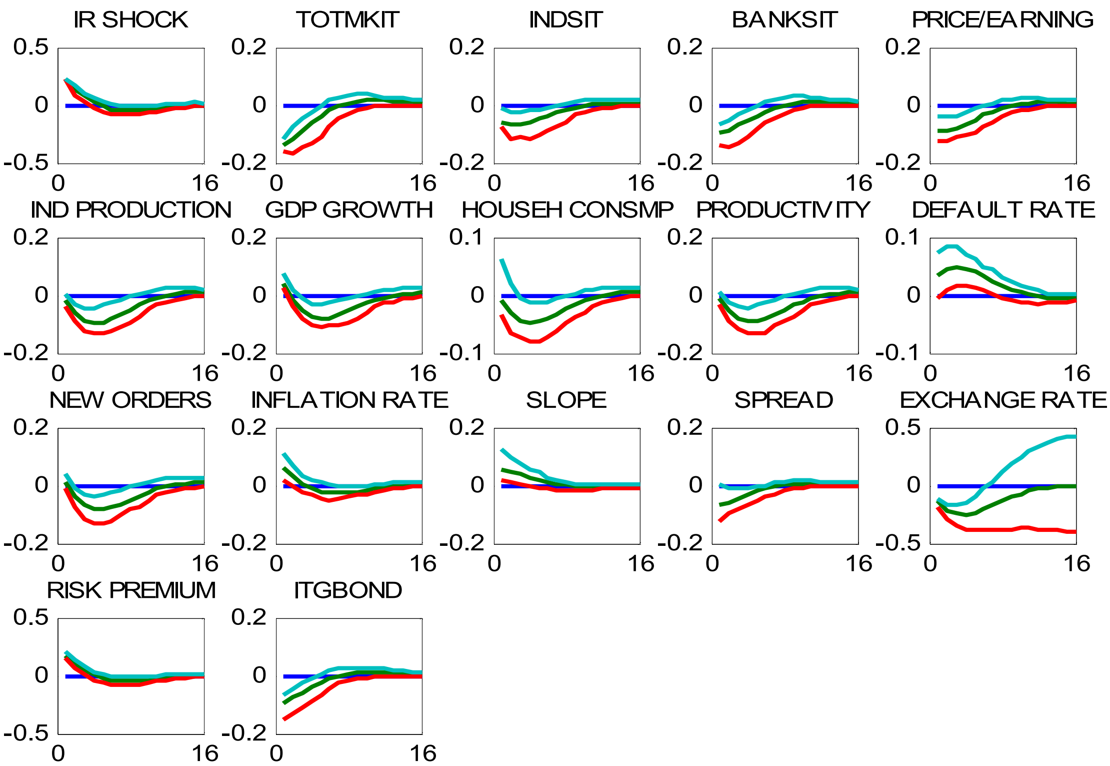
Impulse Responses (green line) generated from the FAVAR with four latent factors and IR estimated by principal components with two-step bootstrap and their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

Figure 6b
IMPULSE RESPONSE FUNCTIONS (3 factors)
Selected Macro and Financial Variables



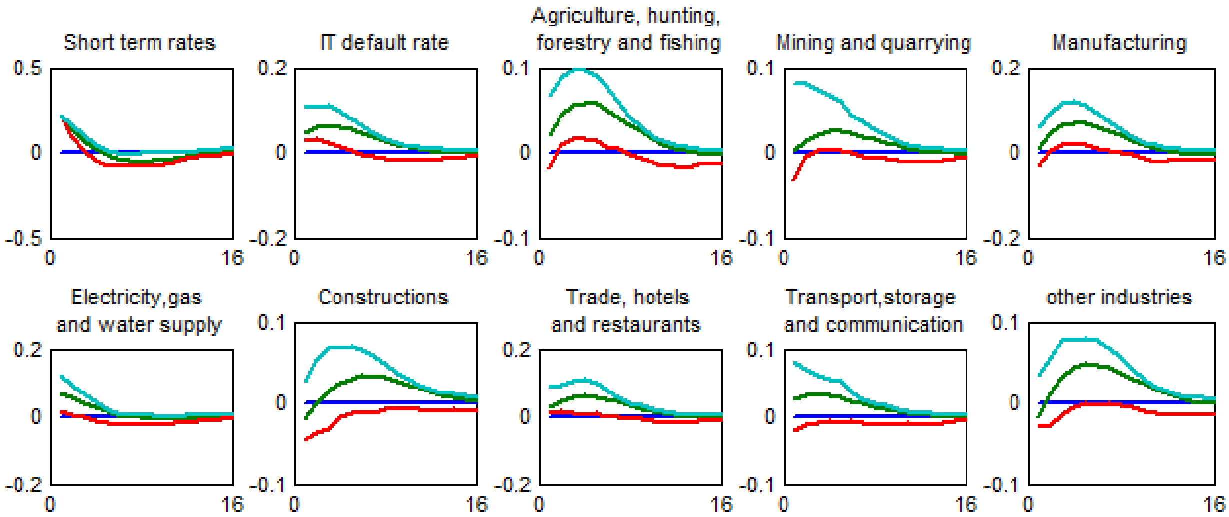
Impulse Responses (green line) generated from the FAVAR with three latent factors and IR estimated by principal components with two-step bootstrap and their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

Figure 6c
IMPULSE RESPONSE FUNCTIONS (2 factors)
Selected Macro and Financial Variables



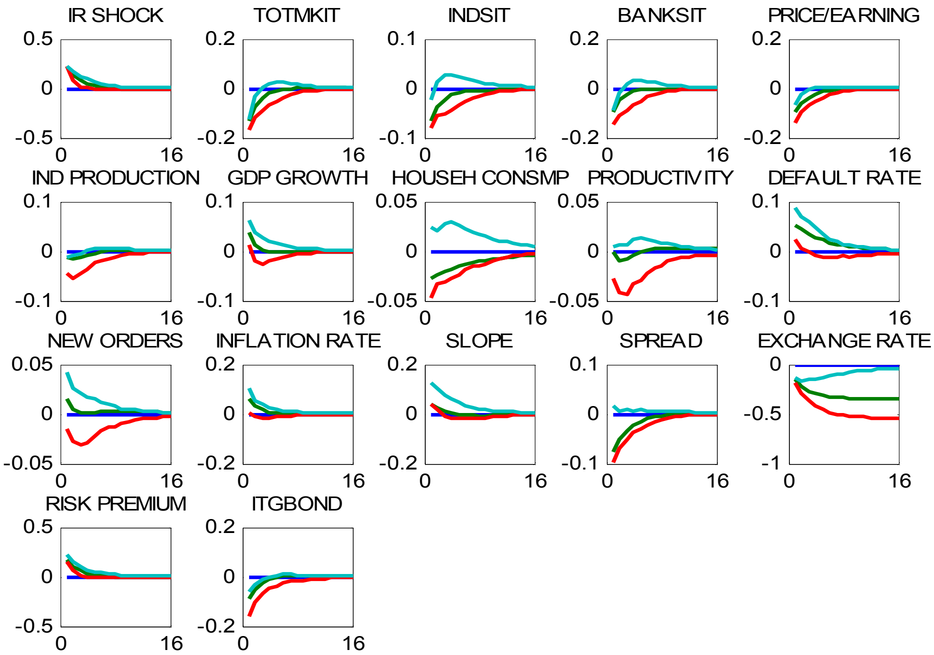
Impulse Responses (green line) generated from the FAVAR with two latent factors and IR estimated by principal components with two-step bootstrap and their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

Figure 7
IMPULSE RESPONSE FUNCTIONS (4 factors)
Sectorial default rates



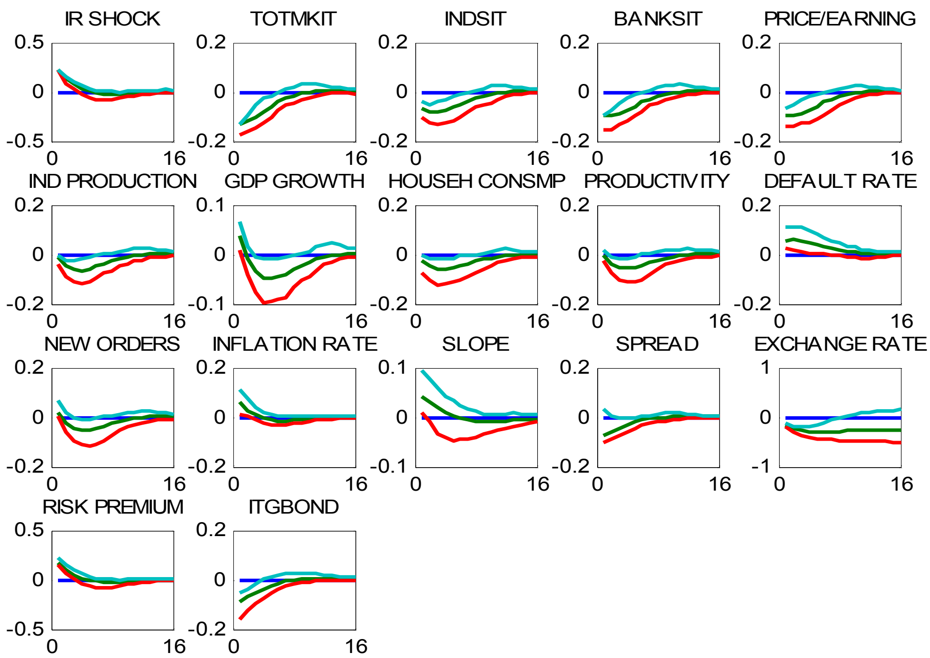
Impulse Responses (green line) generated from the FAVAR with four latent factors and IR estimated by principal components with two-step bootstrap and their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

Figure 8
THE ROLE OF THE INTERACTION AMONG RISK DRIVERS
A. Sterilizing the Equity Risk Driver



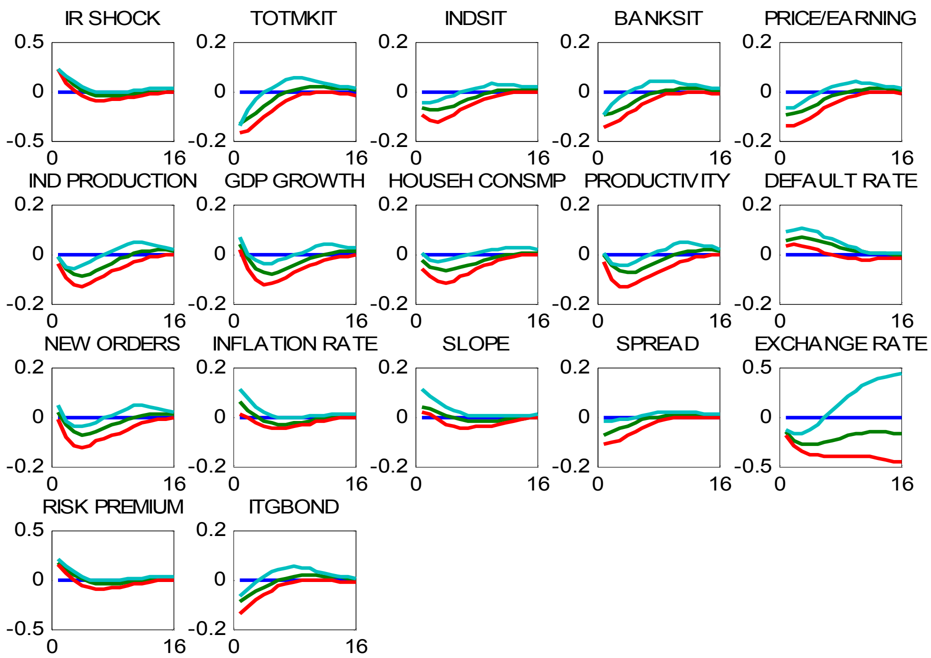
Impulse Responses (green line) generated from the FAVAR model obtained by imposing zero restrictions on the coefficients of the equity risk driver with their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

B. **Sterilizing the Macroeconomic Risk Driver**



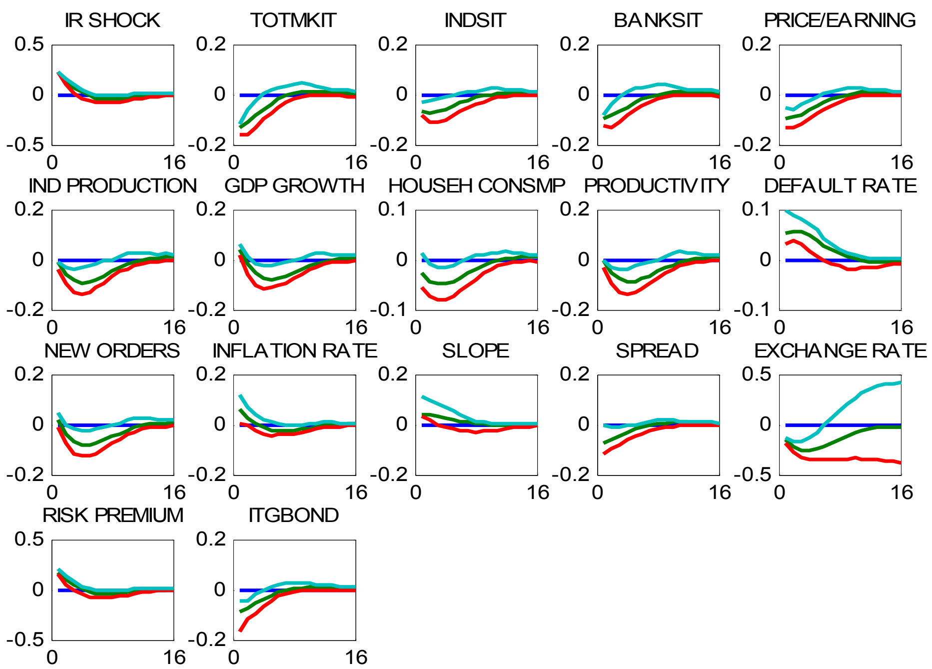
Impulse Responses (green line) generated from the FAVAR model obtained by imposing zero restrictions on the coefficients of the macroeconomic risk driver with their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

C. Sterilizing the Volatility Risk Driver



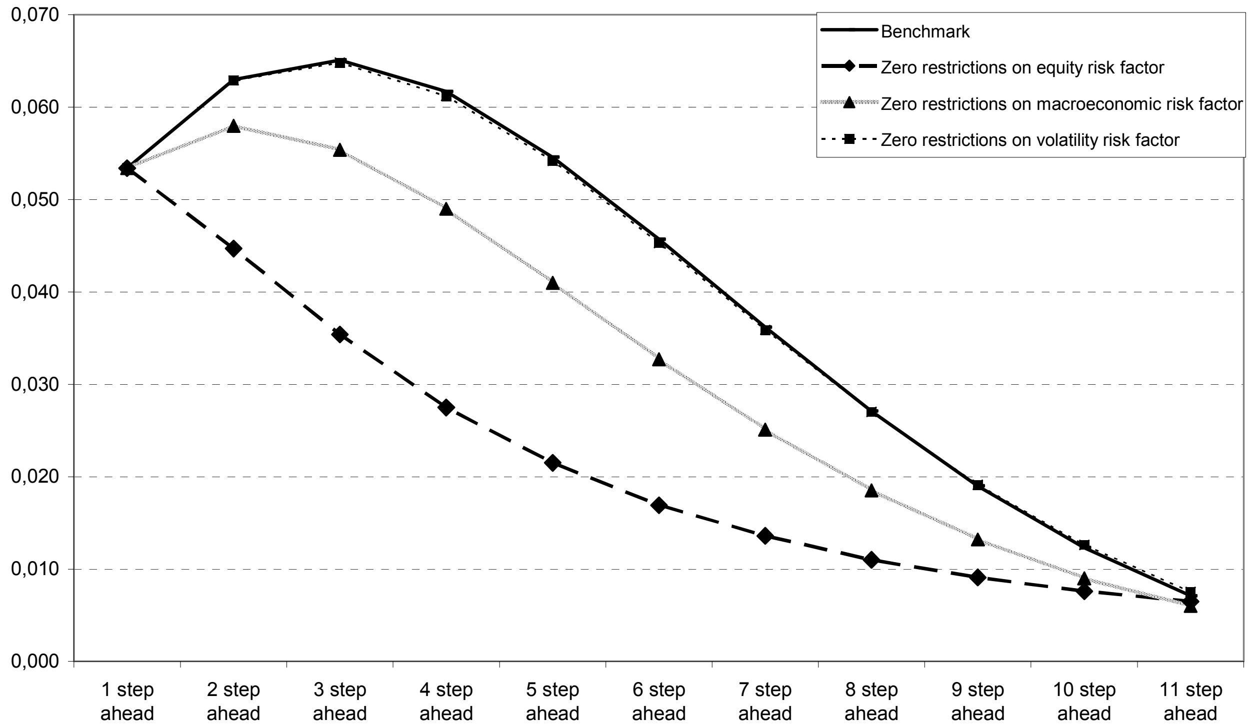
Impulse Responses (green line) generated from the FAVAR model obtained by imposing zero restrictions on the coefficients of the volatility risk driver with their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

D. Sterilizing the Credit Risk Driver



Impulse Responses (green line) generated from the FAVAR model obtained by imposing zero restrictions on the coefficients of the credit risk driver with their respective 90 per cent confidence bands (blue and red lines). All the responses are in standard deviation units.

Figure 9
THE ROLE OF INTERACTION: IMPACT ON AGGREGATE DEFAULT RATES



Estimated impact of a 50 b.p. monetary policy shock on aggregate default rates in the benchmark model and sterilizing, one at a time, the role of the underlying common factors (macroeconomic risk factor, equity risk factor, volatility risk factor) by imposing zero restrictions on the coefficients of the relative equation in the VAR system. Each step is one quarter. All the responses are in standard deviation units.

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