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A factor-augmented model of markup on mortgage loans in Poland

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Abstract

The paper describes the results of estimation of a factor-augmented vector autoregressive model that relates the markup on mortgage loans in national currency, granted to households by monetary financial institutions, and 3-month inter-bank rate that approximates the cost of funds for financial institutions. The factors by which the model is augmented, summarize information that can be used by banks to forecast interest rates and determine risk premium. The estimation results indicate that there is a significant relation between the changes in the markup and the changes in 3-month WIBOR. This relation can be interpreted as evidence of incomplete transmission of shocks from the inter-bank rate to mortgage rates set by banks. The shocks to 3-month WIBOR are partially absorbed by changes in the markup. The relation between the markup and various groups of macroeconomic and financial indicators are studied on the basis of impulse response analysis and structural interpretation of the estimated factors.

Keywords: factor models, interest rates, pass-through, markup

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1. Introduction

An interest rate pass-through model represents a relation between a retail rate set by monetary financial institutions for households and firms and a wholesale market rate approximating marginal cost of funds for financial institutions. Before the emergence of the financial crisis, the empirical literature on the interest rate pass-through focused on the estimation of bivariate models relating a retail rate (e.g. mortgage rate) and a wholesale rate (e.g. EURIBOR) (see Winker 1999; de Bondt 2005).

The extent and the speed of the pass-through were considered as indicators of the effectiveness of monetary policy. An incomplete pass-through was explained by microeconomic factors such as low market competitiveness and credit rationing (see Kot 2004; Chmielewski 2004; Kok-Sørensen, Werner 2006; Gambacorta 2008).

Under conditions of financial turmoil, the effect of short-term market rates on retail rates has become weaker, and the conventional models of the pass-through have turned out to be poor representations of the transmission mechanism. In a few studies the weakened pass-through has been explained by asymmetric adjustment and regime switching (see Becker, Osborn, Yildirim 2012; Aristei, Gallo 2014). Sznajderska (2012), using Polish data, analyzes asymmetries in the pass-through in relation to changes in a few individual macroeconomic and policy indicators, and concludes that many variables may influence the pass-through and it is difficult to select a single one.

In this paper, a large panel of macroeconomic and financial indicators is used to estimate a few common factors which summarize information contained in the data panel. Then a factor-augmented vector autoregressive (FAVAR) model, which measures a relation between the factors, a wholesale rate and the markup of a mortgage rate over the wholesale rate, is estimated. The FAVAR explains deviations from the long-run equilibrium defined by a conventional model of the pass-through for mortgage rates in Poland. Using structural interpretation of the estimated factors and the impulse response analysis, it is possible to evaluate the scope and the persistence of effect of different groups of indicators onto the markup.

The empirical model is motivated by a theoretical forward-looking model which describes a relation between the markup, risk premium and the expectations formed by monetary financial institutions. The common factors summarize information that can be used by monetary financial institutions in the determination of risk premium and the forecasting of future interest rates.

The paper is organized as follows. In the next section we describe a simple theoretical model of the pass-through. Section 3 includes a description of the econometric model. Data description is given in Section 4. The estimation results are reported in Section 5. Section 6 concludes the paper.

2. Aggregation, expectations and the pass-through

Monetary financial institutions (MFI) interest rates statistics adopted in the EU countries, including Poland, provides synthetic retail bank rates that are aggregated into a few broad categories defined by the type of a product, its maturity or the period of initial rate fixation; see *Manual on MFI Interest Rate Statistics* published by the ECB (2003), and *MIR User's Manual* published by Narodowy Bank Polski (2010). Interest rates on outstanding amounts are aggregated by maturity (e.g., outstanding loans for house purchases over 1 year and up to 5 years maturity) and interest rates on new loans are aggregated by the period of initial rate fixation (e.g., new loans for house purchases with the initial rate fixation over 3 months and up to 1 year).

The aggregation is performed by reporting agents (monetary financial institutions): Narodowy Bank Polski (NBP) receives information about interest paid on aggregates, but not on loans of specific maturities or loans with specific periods of initial rate fixation. Since January 2011 NBP no longer publishes MFI interest rates on new loans for house purchases grouped by the periods of initial rate fixation. From that time a single aggregate is only being published.

The economic literature on the interest rate pass-through uses retail rates to match them with money market rates or bond yields defined for specific maturities (see de Bondt 2005). As there is no exact matching of maturities between retail rates and wholesale rates, two approaches are commonly used: either a retail rate is matched to a short-term money market rate (e.g., 3-month EURIBOR), or an appropriate wholesale rate is chosen on the basis of correlation analysis among those rates which are closest to a given retail rate in maturity. A notable exception is the study by Kok-Sørensen and Werner (2006) who construct synthetic wholesale rates.

The first approach, which matches short-term wholesale rates with long-term retail rates, ignores the maturity transformation and is only valid if there is a stable relation between short-term and long-term wholesale rates. The second approach, based on the correlation analysis, uses an ad hoc method which may match different wholesale and retail rates over sub-samples of data, as the value of the correlation coefficient between two interest rates changes over time. The baseline pass-through equation is:

$$r_r = \mu + \beta m_t \tag{1}$$

where:

r_r – a retail bank rate,
m_t – a wholesale rate,
β – the pass-through coefficient,
μ – the bank markup.

The parameters μ and β are said to be determined by the demand elasticity and the market structure (de Bondt 2005). If $\beta < 1$, then the pass-through is said to be incomplete.

An MFI interest rate r_t is a synthetic rate representing a weighted average of retail rates of various maturities and various periods of initial rate fixation:

$$r_t = \sum_{\kappa=\underline{\kappa}}^{\overline{\kappa}} \omega_\kappa \sum_{\tau=\underline{\tau}}^{\overline{\tau}} \omega_{\kappa\tau} r_t(\kappa,\tau) \tag{2}$$

where:

$r_t(\kappa,\tau)$ – a retail rate on new loans with the period of initial rate fixation κ and maturity τ,
$\underline{\kappa}$, $\overline{\kappa}$ – the minimal and the maximal period of initial rate fixation for retail rates included in the synthetic rate r_t,
ω_κ – the weight of loans with the period of initial rate fixation κ ($\sum_{\kappa=\underline{\kappa}}^{\overline{\kappa}} \omega_\kappa = 1$),
$\underline{\tau}, \overline{\tau}$ – the minimal and the maximal maturity,
$\omega_{\kappa\tau}$ – the weight of loans with the period of initial rate fixation κ and maturity τ ($\sum_{\tau=\underline{\tau}}^{\overline{\tau}} \omega_{\kappa\tau} = 1$).

The weights ω_κ and $\omega_{\kappa\tau}(\kappa = \underline{\kappa}, \underline{\kappa+1}\ldots,\overline{\kappa}$ and $\tau = \underline{\tau}, \underline{\tau+1}\ldots,\overline{\tau})$ are not systematically reported by MFIs.

In the Polish market of mortgage loans, the predominant pricing mechanism for loans granted in national currency is to set a retail rate equal to a short-term WIBOR (Warsaw Inter-Bank Offered Rate) plus a markup. Given a short-term rate $m_t(\kappa)$, the pricing mechanism for a new loan with the period of initial rate fixation κ and maturity τ can be described by the equation:

$$r_t(\kappa,\tau) = m_t(\kappa) + z_t(\kappa,\tau) \tag{3}$$

where $z_t(\kappa,\tau)$ is a markup.

The markup depends both on the period of initial rate fixation κ and maturity τ. For a short period of interest rate fixation (small κ), the pricing mechanism allows shifting the interest rate risk from banks to clients, and the markup $z_t(\kappa,\tau)$ is mainly determined by the credit risk and market factors (demand elasticity and market concentration). By substitution, for an aggregated rate:

$$r_t = \sum_{\kappa=\underline{\kappa}}^{\overline{\kappa}} \omega_\kappa \left(\sum_{\tau=\underline{\tau}}^{\overline{\tau}} \omega_{\kappa\tau}\, z_t(\kappa,\tau) + m_t(\kappa) \right) \tag{4}$$

Consider a modification of the linearized expectations model proposed by Shiller (1979), which relates a wholesale rate $m_t(\kappa)$ to the expected path of the rate $m_t(\underline{\kappa})$ ($\underline{\kappa}$ is the minimal period of initial rate fixation)

$$m_t(\kappa) = \phi_t(\kappa) + \frac{1-\gamma^{\underline{\kappa}}}{1-\gamma^{\kappa/\underline{\kappa}}} \sum_{h=0}^{[\kappa/\underline{\kappa}]-1} \gamma^{h\underline{\kappa}} E_t m_{t+h\underline{\kappa}}(\underline{\kappa}) \tag{5}$$

where:

$\phi_t(\kappa)$ – time-varying term premium,

γ – a discount factor,

$E_t m_{t+h\underline{\kappa}}(\kappa)$ – the expectation of the $\underline{\kappa}$-period rate.

After rearrangement, using $\Delta^{(h\underline{\kappa})} m_{t+h\underline{\kappa}}(\kappa) = m_{t+h\underline{\kappa}}(\kappa) - m_t(\kappa)$:

$$m_t(\kappa) = \phi_t(\kappa) + m_t(\underline{\kappa}) + \frac{1-\gamma^{\underline{\kappa}}}{1-\gamma^{\kappa/\underline{\kappa}}} \sum_{h=1}^{[\kappa/\underline{\kappa}]-1} \gamma^{h\underline{\kappa}} E_t \Delta^{(h\kappa)} m_{t+h\underline{\kappa}}(\underline{\kappa}) \tag{6}$$

By substitution (for $\overline{\kappa} \geq 2\underline{\kappa}$):

$$\begin{aligned} r_t = m_t(\underline{\kappa}) &+ \sum_{\kappa=\underline{\kappa}}^{\overline{\kappa}} \omega_\kappa \left(\sum_{\tau=\underline{\tau}}^{\overline{\tau}} \omega_{\tau\kappa} z_t(\kappa,\tau) + \phi_t(\kappa) \right) + \\ &+ \sum_{\kappa=2\underline{\kappa}}^{\overline{\kappa}} \omega_\kappa \left(\frac{1-\gamma^{\underline{\kappa}}}{1-\gamma^{\kappa/\underline{\kappa}}} \sum_{h=1}^{[\kappa/\underline{\kappa}]-1} \gamma^{h\underline{\kappa}} E_t \Delta^{(h\kappa)} m_{t+h\underline{\kappa}}(\underline{\kappa}) \right) \end{aligned} \tag{7}$$

and after rearrangement:

$$r_t = \mu_t + m_t(\underline{\kappa}) + \sum_{h=1}^{[\kappa/\underline{\kappa}]-1} \delta_h E_t \Delta^{(h\underline{\kappa})} m_{t+h\underline{\kappa}}(\underline{\kappa}) \tag{8}$$

where:

$$\mu_t = \sum_{\kappa=\underline{\kappa}}^{\overline{\kappa}} \omega_\kappa \left(\sum_{\tau=\underline{\tau}}^{\overline{\tau}} \omega_{\kappa\tau} z_t(\kappa,\tau) + \phi_t(\kappa) \right) \text{ and } \delta_h = \sum_{\kappa=2\underline{\kappa}}^{\overline{\kappa}} \omega_\kappa \frac{1-\gamma^{\kappa}}{1-\gamma^{\kappa/\underline{\kappa}}} \gamma^{h\underline{\kappa}} \tag{9}$$

The synthetic retail rate r_t can be expressed as a function of a spot short-term rate and expected changes in the short-term rate up to the maximal period of initial rate fixation for retail rates included in the synthetic rate r_t. The residual variability of the retail rate can be explained by the fluctuations in risk premium and market factors.

In Poland, 3-month WIBOR is the most common choice of the index rate $m_t(\kappa)$. The aggregated markup, defined as a difference between the retail rate on new mortgage loans and 3-month WIBOR ($\underline{\kappa}$ = 3 months), is given by:

$$z_t = r_t - m_t(\underline{\kappa}) = \mu_t + \sum_{h=1}^{[\kappa/\underline{\kappa}]-1} \delta_h E_t \Delta^{(h\underline{\kappa})} m_{t+h\underline{\kappa}}(\underline{\kappa}) \tag{10}$$

In this model, persistent changes in the markup z_t are caused by changes in the risk premium and revisions of forecasts by monetary financial institutions. The persistent changes in the markup mean that any shock to an inter-bank rate is not fully transmitted to retail mortgage rates. If the shock to the inter-bank rate was caused by the monetary policy shock, then it would be weakened by the incomplete pass-through from the inter-bank rate to retail rates.

In pass-through models inter-bank offered rates are supposed to approximate marginal cost of funds for banks. However, these rates are indices which are not computed on the basis of actual transactions. In some subperiods, including the period of financial turbulence, actual inter-bank rates (based on transactions) could deviate from WIBORs of corresponding maturities. However, because actual inter-bank rates are not publicly available, it is difficult to measure the extent of these deviations (except for the overnight POLONIA rate which was systematically lower than overnight WIBOR).

The deviations of actual inter-bank rates from WIBORs could have contributed to changes in the markup measured as a difference between the mortgage rate and a WIBOR. If an actual inter-bank rate was larger than the WIBOR of the corresponding maturity, then the markup over the WIBOR was large in comparison with the markup over the actual rate, which implied the weakening of the pass-through from the WIBOR to the mortgage rate. By including a number of financial indicators and risk proxies in the factor model, we try to control for the sources of these deviations in the factor-augmented VAR.

3. Econometric model

In this paper a dynamic factor model is employed to summarize information that can be used by MFIs in making projections of future interest rates and determining a risk premium. In a similar study, Banerjee, Bystrov and Mizen (2013) estimated a pass-through model where recursive forecasts of a market rate were included into a dynamic regression. The forecasts were based on a factor model of the yield curve. Although the study confirmed the importance of forecasts in the retail rate setting, the forecasts were based on the information contained in the yield curve only and the risk premium was assumed to be constant. The performance of the model may be improved by extending the information set with other macroeconomic and financial variables that might be useful in the forecasting of market rates and the determination of the risk premium.

We model expectations of MFIs as based on a dynamic factor model which represents an extensive set of macroeconomic and financial variables by a few common factors:

$$X_t = \Lambda F_t + e_t \tag{11}$$

where:

X_t – ($N \times 1$) vector of observed macroeconomic and financial indicators,
F_t – ($R \times 1$) vector of unobserved common factors ($R << N$),
Λ – ($N \times R$) matrix of loadings,
e_t – ($N \times 1$) vector of idiosyncratic components.

Stock and Watson (1998a) provide assumptions which are sufficient for consistent estimation of common factors by the principal components method and asymptotic efficiency of factor-based forecasts.

The common factors parsimoniously summarize the information which can be used by MFIs in forecasting future interest rates, and the factor-based forecasts can serve as an approximation of the expectations formed by MFIs. However, the information, summarized by the common factors, may also be used in the determination of the risk premium.

Therefore, the inclusion of factor-based forecasts in a pass-through model, while assuming a constant risk premium, may not be recommended. The risk premium can be time-varying and dependent on the macroeconomic indicators which are included in the factor model. In this paper, a dynamic model of the pass-through is augmented by the estimated common factors, assuming that the information, which is summarized by these factors, may determine both expectations and the risk premium.

If there is a complete pass-through from 3-month WIBOR to the mortgage rate, i.e., changes in $m_t = m_t(3)$ are completely transmitted into changes in r_t, then markup $z_t = m_t - r_t$ should be a stationary variable. However, the results of the unit root tests performed for z_t indicate that it is not stationary (see Table 1). Hence, first differences Δz_t are modeled.

A bivariate vector autoregression, including Δz_t, and Δm_t, is augmented by a few factors $\hat{F}_t$ extracted from a large number of macroeconomic and financial indicators:

$$\begin{bmatrix} \hat{F}_t \\ \Delta m_t \\ \Delta z_t \end{bmatrix} = \begin{bmatrix} \mu_F \\ \mu_m \\ \mu_z \end{bmatrix} + \begin{bmatrix} \Phi(L) & 0 & 0 \\ \alpha(L)' & a(L) & b(L) \\ \beta(L)' & c(L) & d(L) \end{bmatrix} \begin{bmatrix} \hat{F}_{t-1} \\ \Delta m_{t-1} \\ \Delta z_{t-1} \end{bmatrix} + \begin{bmatrix} \eta_t \\ \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \tag{12}$$

where:

$\hat{F}_t$ – ($R \times 1$) vector of estimated common factors,
$\Phi(L)$ – $(R \times R)$ matrix lag polynomial,
$\alpha(L), \beta(L)$ – $(R \times 1)$ vector polynomials,
$a(L)$, $b(L)$, $c(L)$, $d(L)$ – scalar polynomials.

The common factors F_t are assumed to be exogenous with respect to Δz_t and Δm_t (for a motivation of this restriction, see Stock, Watson 2005). Therefore, zero restrictions are imposed on the lags of Δz_t and in Δm_t the equations for the common factors.

The common factors are estimated using the principal components estimator. Bai and Ng (2006) provide central limit theorems and confidence intervals for inference in factor-augmented regressions. We implement Bai and Ng (2006) methodology: parameters of the factor-augmented regressions are estimated using the least squares estimator and heteroscedasticity-consistent standard errors are computed to account for consequences of including generated regressors in the model.

4. Data

The FAVAR model is estimated using monthly data from January 2004 to June 2014. The markup is computed as a difference between the average rate on new mortgage loans granted in national currency and the monthly average of 3-month WIBOR. It is a synthetic measure of markup that can only be interpreted as an approximation of the actual markup set by MFIs.

The mortgage rate is extracted from the monetary and financial statistics of Narodowy Bank Polski. The rate on new business volumes is chosen over the rate on outstanding amounts of mortgage loans, because rates on new business volumes are used more often in the literature on the interest rate pass-through. These rates represent costs of new loans rather than costs of loans granted in the past which are represented by rates on outstanding amounts. Figure 1 shows the time series plot of the mortgage rate, 3-month WIBOR and the markup, and Figure 2 shows the plot of differences of 3-month WIBOR (Δm_t) and the markup (Δz_t).

The common factors are estimated using 54 time series which cover industrial production, prices, exchange rates, interest rates, monetary aggregates, stock exchange indices and credit risk indicators (see Table 2 in the Appendix). The leading business indicators were initially included in the factor model. However, as their correlation with the estimated common factor was negligible, these indicators were eventually excluded from the data panel. The data series were extracted from databases of a few institutions: Narodowy Bank Polski, the Central Statistical Office of Poland (GUS), the Warsaw Stock Exchange (GPW), Eurostat, the European Central Bank (ECB), the OECD, the IMF and Bloomberg. The composition of the data panel is aimed to provide a balanced representation of all sectors of the Polish economy.

Prior to the estimation of the factor model, the data were processed using Stock and Watson (1998a) methodology. First, all series that were modeled as generated by integrated processes, were transformed to stationary series, using differences or log-differences. Second, all non-financial time series were seasonally adjusted using Census X12-ARIMA procedure. Third, outliers exceeding the interquartile difference by a factor of six, were substituted by missing values that were subsequently substituted by estimates obtained using the expectation-maximization (EM) algorithm. (The total of 6 out of 54 variables were found to contain outliers). Fourth, all series were standardized to have zero mean and unit variance.

5. Estimation results

The common factors were estimated using the principal component estimator. First, the estimation was performed on a panel of series including no missing values. Second, missing values were interpolated using the EM algorithm and the factors were estimated using the whole panel.

Initially, ten common factors were estimated. Of those, five factors were selected using a threshold of at least 5% of the total variance explained by each selected factor (for an application of such criterion see Forni, Reichlin 1998). These five factors explain 58% of the total variance of the 54 time series. The time series plot of these factors is shown in Figure 3 and the loadings of these factors onto individual time series are presented in Figure 4.

The first factor loads on nominal indicators: producer price inflation, returns on exchange rates and stock indices, and changes in sovereign CDS spreads. The second factor loads on indicators of industrial production, wages and employment. The third factor is correlated with interest rates. The fourth factor has the highest correlation with indicators of consumer and producer price inflation and the fifth factor has a high correlation with monetary aggregates.

The selection of the FAVAR model was carried out using system SER (Sequential Elimination of Regressors) procedure based on the Bayesian information criterion (Brüggemann, Lütkepohl 2001). The initial model included five factors and six lags of factors, the difference of 3-month WIBOR and the difference of markup. The final model included five factors and up to three lags of each variable.

The results of the model estimation are summarized by the cumulative orthogonalized impulse responses of the mortgage markup and 3-month WIBOR presented in Figure 5 and 6. The figures show the 90% joint bootstrap confidence bands obtained using the neighbouring paths method proposed by Staszewska (2007) (see also Staszewska-Bystrova 2011). The joint band contains the entire response function constructed for a given response horizon with probability 0.90. The impulse responses are accumulated, i.e., the results have the form of impulse responses of the variables in levels, m_t and z_t, derived from the FAVAR model (12) which is estimated using differences Δm_t and Δz_t.

The assumed ordering of variables in the FAVAR means that common factors can have an immediate effect onto the 3-month WIBOR and the markup. However, 3-month WIBOR and the markup have no immediate effect on the common factors. This is consistent with the interpretation of the common factors as exogenous latent variables that describe a state of the economy. The ordering of the variables also implies that the 3-month WIBOR may have an immediate impact onto the markup, but not vice versa.

Figure 5 shows the cumulative orthogonalized impulse responses of the markup, z_t, to shocks in factors 1–5 and in the first differences of 3-month WIBOR, Δm_t. Each shock is equal to one standard deviation of residuals in the estimated equation for a corresponding variable.

A shock in the first differences of 3-month WIBOR, Δm_t, as a permanent negative effect on the markup, z_t. It implies that if the level of 3-month WIBOR unexpectedly but permanently increases, then the markup decreases: a part of the increase in the WIBOR is not transferred to an increase in mortgage rates – it is absorbed by a decrease in the markup.

There are significant effects of the estimated factors onto the markup. The direction of these effects should be interpreted cautiously though, as factors are identified up to a linear transformation. However, it can be concluded that one has to control for other macroeconomic and financial indicators when measuring the response of the markup to a short-term market rate.

The markup changes permanently in response to shocks in factor 1 correlated with financial indicators, in particular, exchange rates, stock indices an CDS spreads, which measure the credit risk premium. The response of the markup to factor 1 can be interpreted as the response to changes in exchange rates and in the risk premium at international financial markets.

Before the emergence of financial turmoil in 2008–2009, a large share of mortgage loans in Poland was granted in foreign currencies (Swiss franc and euro). However, the depreciation of the national currency led to an increase of a share of non-performing loans in this segment of the market. An introduction of a more stringent regulation of mortgage loans resulted in a sharp decrease of the volume of new loans granted in foreign currencies, which were to a large extent substituted by the loans granted in national currency. In order to compensate losses cause by non-performing loans in foreign currencies, MFIs responded by an increase of the markup on new loans granted in national currency.

The substitution effect is not directly modeled in the paper. However, factor 1 is correlated both with changes of exchange rated and changes of the outstanding amount of mortgage loans granted in foreign currencies. The significant impact of factor 1 onto the markup on new mortgage loans granted in national currency is consistent with the interpretation of the increased markup in 2008–2009 as resulting from an increase in the credit risk premium caused by the exchange rate fluctuations and an increase of a share of non-performing loans in foreign currencies.

The markup changes permanently in response to shocks in factor 2 which is correlated with industrial production, employment and wages. These indicators are related with the ability of retail clients to pay their mortgages. The significant response of the markup to this factor can be interpreted as the response to the information about credit risk at the retail loan market.

There is a temporary response of the markup to a shock in factor 3 which is correlated with other interest rates. Since longer-term interest rates contain information about future dynamics of 3-month WIBOR, a shock to these rates can be interpreted as a revision of expectations about 3-month WIBOR. Given that rates on new mortgage loans are fixed for some initial period, revisions of expectations about 3-month WIBOR are compensated by changes in the markup. However, since the period of initial rate fixation is typically not very long, the response of the markup to revised expectation about 3-month WIBOR is only temporary.

Factors 4 and 5, correlated with consumer prices inflation and monetary aggregates, have no significant effect onto the markup.

The cumulative orthogonal impulse responses of the 3-month WIBOR are shown in Figure 6. There are significant permanent responses of 3-month WIBOR to shocks in factors correlated with growth rates of industrial production, changes in other interest rates, and consumer price inflation. These factors summarize information of potential use in the forecasting of 3-month WIBOR. There is no feedback from the markup to 3-month WIBOR, as lags of the markup are excluded from the equation for the first differences of WIBOR by the model selection procedure, and the markup is assumed to have no instantaneous effect on the WIBOR.

In order to investigate the parameter stability of the estimated FAVAR model, we implement the Andrews (1993) and the Andrews-Ploberger tests (1994), which are based on the supremum Wald statistic and the average exponential Wald statistic respectively. It was demonstrated in several studies (see Stock, Watson 1998b; Hansen 2000; Cogley, Sargent 2005) that these tests have the highest power, as compared to other popular tests, to detect parameter instability in dynamic regressions.

Following Stock and Watson (1998b), we implement a heteroscedasticity-robust version of these tests and compute bootstrapped critical values to account for a small sample size. The Andrews and the Andrews-Ploberger tests are not based on the assumption of a specific date of structural change, but evaluate stability of the parameters over a window of observations. We selected a symmetric window, trimming 25% of the observations at the beginning and at the end of the estimation sample. As a result, the stability of parameters was tested over the period from October 2006 to November 2010. A choice of a larger window would lead to computational instability of the least square estimator.

Table 3 reports computed test statistics together with bootstrapped and asymptotic critical values for the 5% level of significance. The results are provided for each equation of the FAVAR model and for the model as a whole. The test statistics of both tests are smaller than bootstrapped and asymptotic critical values for all equations of the model. Therefore, the null hypothesis of parameter stability cannot be rejected given the significance level of 5%. No evidence of parameter instability in the FAVAR model is found.

6. Conclusions

In this paper, a factor-augmented VAR model is used to explain the relation between changes in 3-month WIBOR and the markup on new mortgage loans in national currency which are granted to households by monetary financial institutions. The augmentation of a simple VAR model is motivated by the forward-looking behavior of monetary financial institutions that determine the markup on mortgage loans in dependence on their projections of future interest rates and the risk premium. The common factors, which are computed using a large panel of economic and financial time series, summarize, in a parsimonious way, the information used by monetary financial institutions.

The estimation results confirm that there is a significant relation between the markup and changes in 3-month WIBOR. It implies that any shock to 3-month WIBOR is only partially transmitted to mortgage rates paid by households on housing loans. The changes in 3-month WIBOR are partially absorbed by changes in the markup. The common factors, which summarize information flowing from financial markets as well as the real sector of the economy, are found to be significant in the model, which means that additional information summarized by these factors influences the pricing behavior of financial institutions.

A few extensions of the research are possible. First, additional assumptions can be imposed and a structural FAVAR can be estimated in order to provide a more profound economic interpretation of the impulse response analysis. Second, instead of considering heteroscedasticity-robust estimator, the direct modelling of heteroscedasticity can be implemented. Third, an explicit measure of the risk premium can be derived, using the dynamic factor model, and its effect onto the markup can be evaluated. Fourth, a FAVAR model can be used to study pass-through in other sectors of the credit market (e.g., consumer and corporate loans).

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Appendix

Table 1
Unit root tests, 5-percent level of significance

Elliott, Rothenberg, Stock test (1996); H_0: unit root*			
variable	**number of lags**	**test statistic**	**critical value**
3-month WIBOR	4	-1.774	-1.940
Markup	7	-1.752	
Kwiatkowski, Phillips, Schmidt, Shin test (1992); H_0: no unit root			
variable	**number of lags**	**test statistic**	**critical value**
3-month WIBOR	4	1.092	0.463
	12	0.504	
Markup	4	1.254	
	12	0.545	

*H_0 is rejected if absolute value of test statistic is larger than critical value.

Table 2
Description of data panel

Mnemonic	Description	Data source	Seasonal adjustment	Transformation code
Retail.Vol	Retail trade, index of deflated turnover	Eurostat	Yes	2
IP.Manuf	Manufacturing, volume index of production	Eurostat	Yes	2
IP.Mining	Mining and quarrying, volume index of production	Eurostat	Yes	2
IP.Constr	Construction, volume index of production	Eurostat	Yes	2
IP.Energy	Energy, volume index of production	Eurostat	Yes	2
IP.Non.Dur	Non-durable consumption goods, volume index of production	Eurostat	Yes	2
IP.Dur	Durable consumption goods, volume index of production	Eurostat	Yes	2
IP.Interm	Intermediate goods, volume index of production	Eurostat	Yes	2

IP.Cap	Capital goods, volume index of production	Eurostat	Yes	2
Exports	Total exports, current prices, PLN mn	GUS	Yes	2
Imports	Total imports, current prices, PLN mn	GUS	Yes	2
Empl.Manuf	Employment (number of people employed), manufacturing	Eurostat	Yes	2
Wages.Manuf	Gross wages and salaries, index	Eurostat	Yes	2
PPI.Energy	Producer price index, energy	Eurostat	Yes	2
PPI.Mining	Producer price index, mining and quarrying	Eurostat	Yes	2
PPI.Manuf	Producer price index, manufacturing	Eurostat	Yes	2
PPI.Food	Producer price index, food	Eurostat	Yes	2
PPI.Non.Dur	Producer price index, non-durable consumption goods	Eurostat	Yes	2
PPI.Dur	Producer price index, durable consumption goods	Eurostat	Yes	2
PPI.Interm	Producer price index, intermediate goods	Eurostat	Yes	2
PPI.Cap	Producer price index, capital goods	Eurostat	Yes	2
CPI.Food	Consumer price index, food	OECD	Yes	2
CPI.All	Consumer price index, all items, non-food, non-energy	OECD	Yes	2
HICP.All	Harmonized index of consumer prices, all items	OECD	Yes	2
CPI.Energy	Consumer price index, energy	OECD	Yes	2
Brent.Price	Petroleum price, Brent, light blend U.K.	IMF	No	2
PLNUSD	Exchange rate, PLN/USD, monthly average	NBP	No	2
PLNEUR	Exchange rate, PLN/ EUR, monthly average	NBP	No	2
PLNCHF	Exchange rate, PLN/CHF, monthly average	NBP	No	2
NEER42	Nominal effective exchange rate – 42 trading partners	Eurostat	Yes	2
REER42	Real effective exchange rate – 42 trading partners	Eurostat	Yes	2
M1	Monetary aggregate M1, PLN mn	NBP	Yes	2
M2	Monetary aggregate M2, PLN mn	NBP	Yes	2
M3	Monetary aggregate M3, PLN mn	NBP	Yes	2

Mortg.FC	Outstanding amounts of mortgage loans granted in foreign currency, PLN mn	NBP	Yes	2
Mortg.PLN	Outstanding amounts of mortgage loans granted in national currency, PLN mn	NBP	Yes	2
WIBOR.ON	Overnight WIBOR, monthly average	Eurostat	No	1
WIBOR.1M	1-month WIBOR, monthly average	Eurostat	No	1
WIBOR.6M	6-month WIBOR, monthly average	Eurostat	No	1
WIBOR.12M	12-month WIBOR, monthly average	Eurostat	No	1
Bond.2Y	Government bond yield, 2 years maturity	Bloomberg	No	1
Bond.5Y	Government bond yield, 5 years maturity	Bloomberg	No	1
Bond.10Y	Government bond yield, 10 years maturity	Bloomberg	No	1
DepRate.PLN	Rate on zloty deposits by households, new business, PLN mln	NBP	No	1
EURIBOR3M	3-month EURIBOR	ECB	No	1
LIBOR3M.CHF	3-month LIBOR, Swiss franks	ECB	No	1
CDS.2Y	Sovereign CDS spread, 2 years, USD	Bloomberg	No	1
CDS.5Y	Sovereign CDS spread, 5 years, USD	Bloomberg	No	1
CDS.10Y	Sovereign CDS spread, 10 years, USD	Bloomberg	No	1
WIG	Warsaw Stock Exchange Index, monthly average	GPW	No	2
WIGBanks	Warsaw Stock Exchange Index, banks, monthly average	GPW	No	2
EuroStoxx50	Dow Jones EuroStoxx 50 index, monthly average	ECB	No	2
SP500	Standard and Poors' 500 index, monthly average	ECB	No	2
VIX	CBOE volatility index, monthly average	ECB	No	1

Notes:
GUS – Central Statistical Office of Poland, GPW – Warsaw Stock Exchange, NBP – Narodowy Bank Polski, ECB – European Central Bank, IMF – International Monetary Fund, OECD – Organization for Economic Co-operation and Development
Seasonal adjustment: Yes – series was adjusted, No – series was not adjusted
Transformation code: 0 – no transformation, 1– difference, 2 – log-difference.

Table 3

Stability tests, 5% level of significance

Andrews test			
equation	**bootstrap test statistic**	**critical value**	**asymptotic critical value**
F_{1t}	8.127	9.209	17.250
F_{2t}	10.807	15.274	20.950
F_{3t}	4.861	11.448	19.070
F_{4t}	4.639	6.611	13.160
F_{5t}	3.395	3.672	7.930
Δ_{mt}	10.804	12.568	20.630
Δz_t	6.208	6.384	13.160
All	31.360	36.209	NA
Andrews-Ploberger test			
equation	**bootstrap test statistic**	**critical value**	**asymptotic critical value**
F_{1t}	2.185	3.025	5.960
F_{2t}	3.764	5.289	8.430
F_{3t}	1.655	3.763	6.790
F_{4t}	0.835	1.982	4.150
F_{5t}	0.852	0.853	2.010
Δ_{mt}	3.208	4.459	7.490
Δ_{zt}	1.725	1.820	4.150
All	13.365	15.262	NA

Figure 1
Time series plot of mortgage rate, 3-month WIBOR, and markup

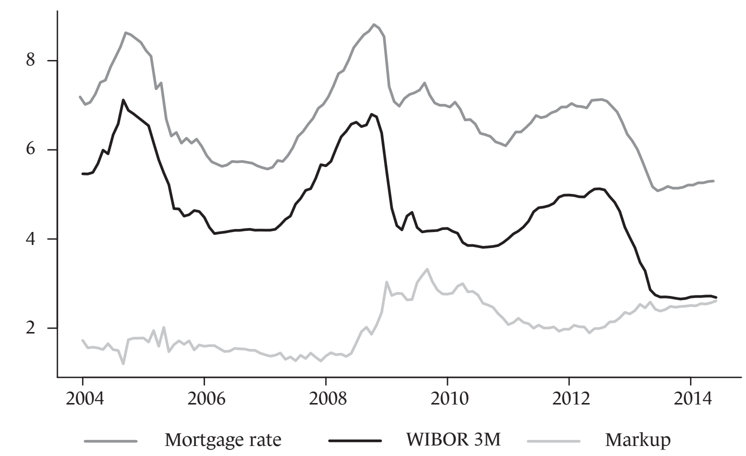

Figure 2
Time series plot of differences of 3-month WIBOR and markup

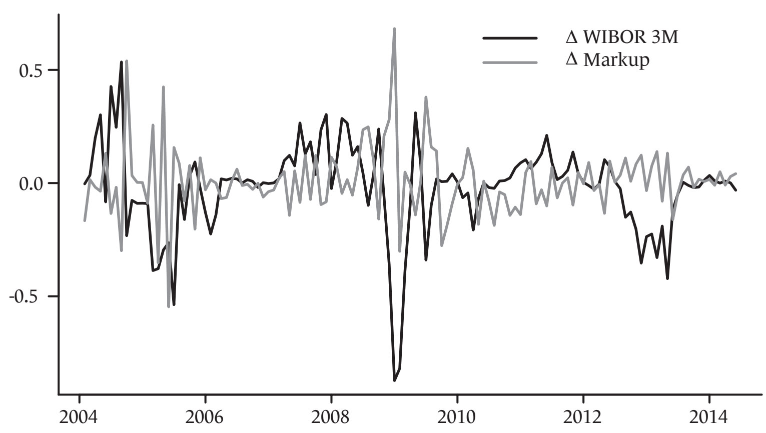

Figure 3
Time series plots of five factors

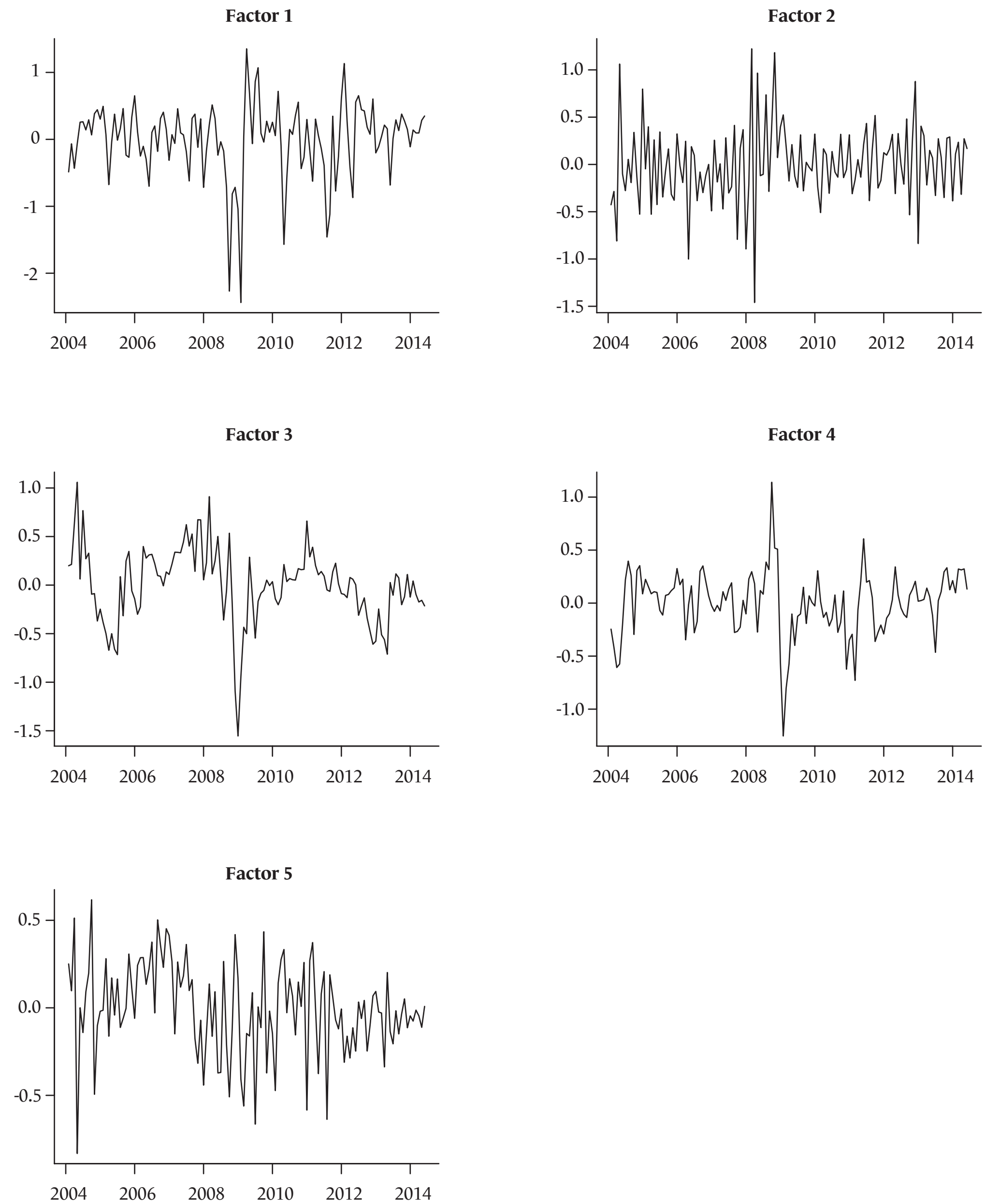

Figure 4
Loadings of factors on individual time series

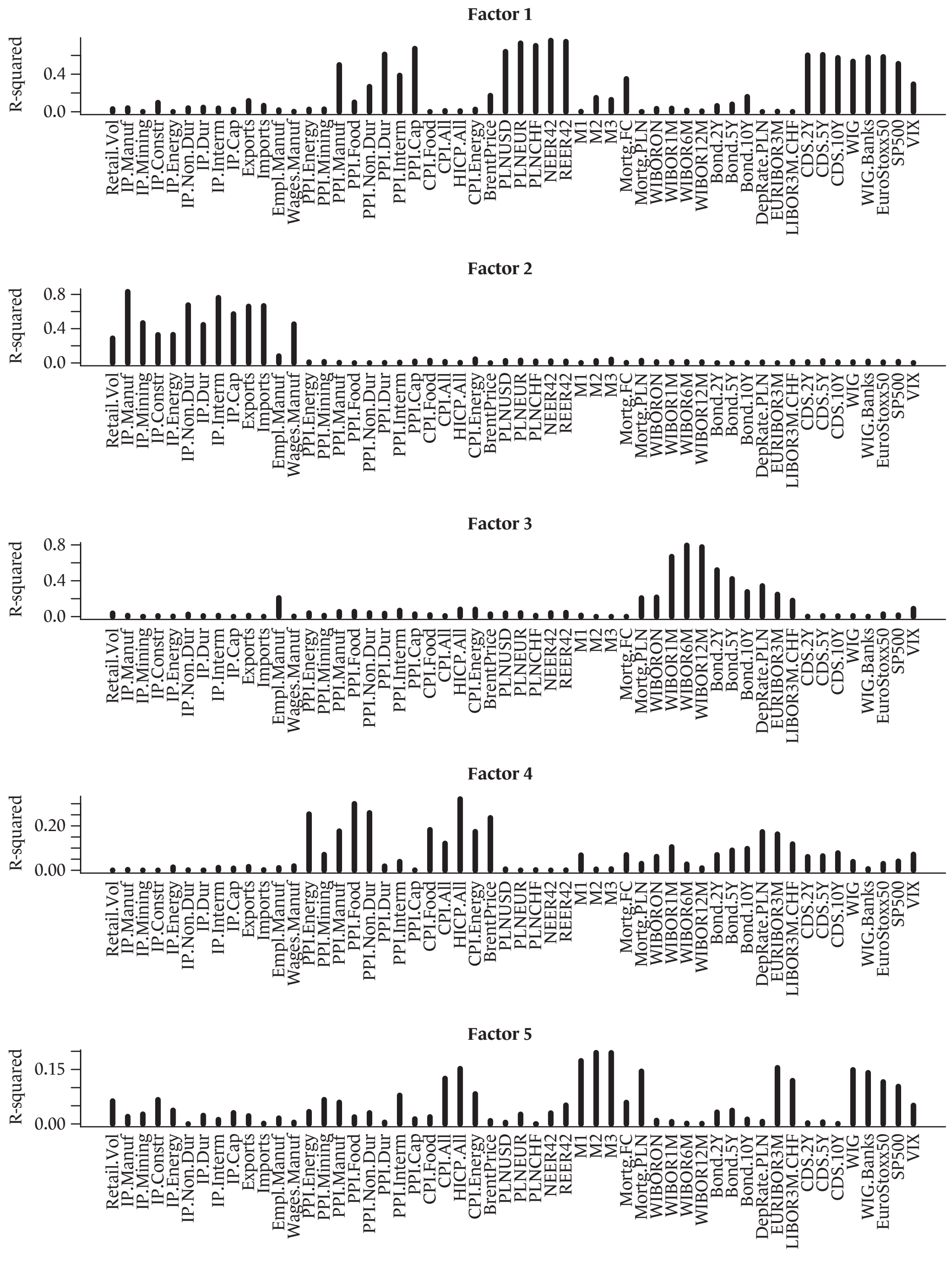

Figure 5
Cumulative orthogonalized impulse responses of markup

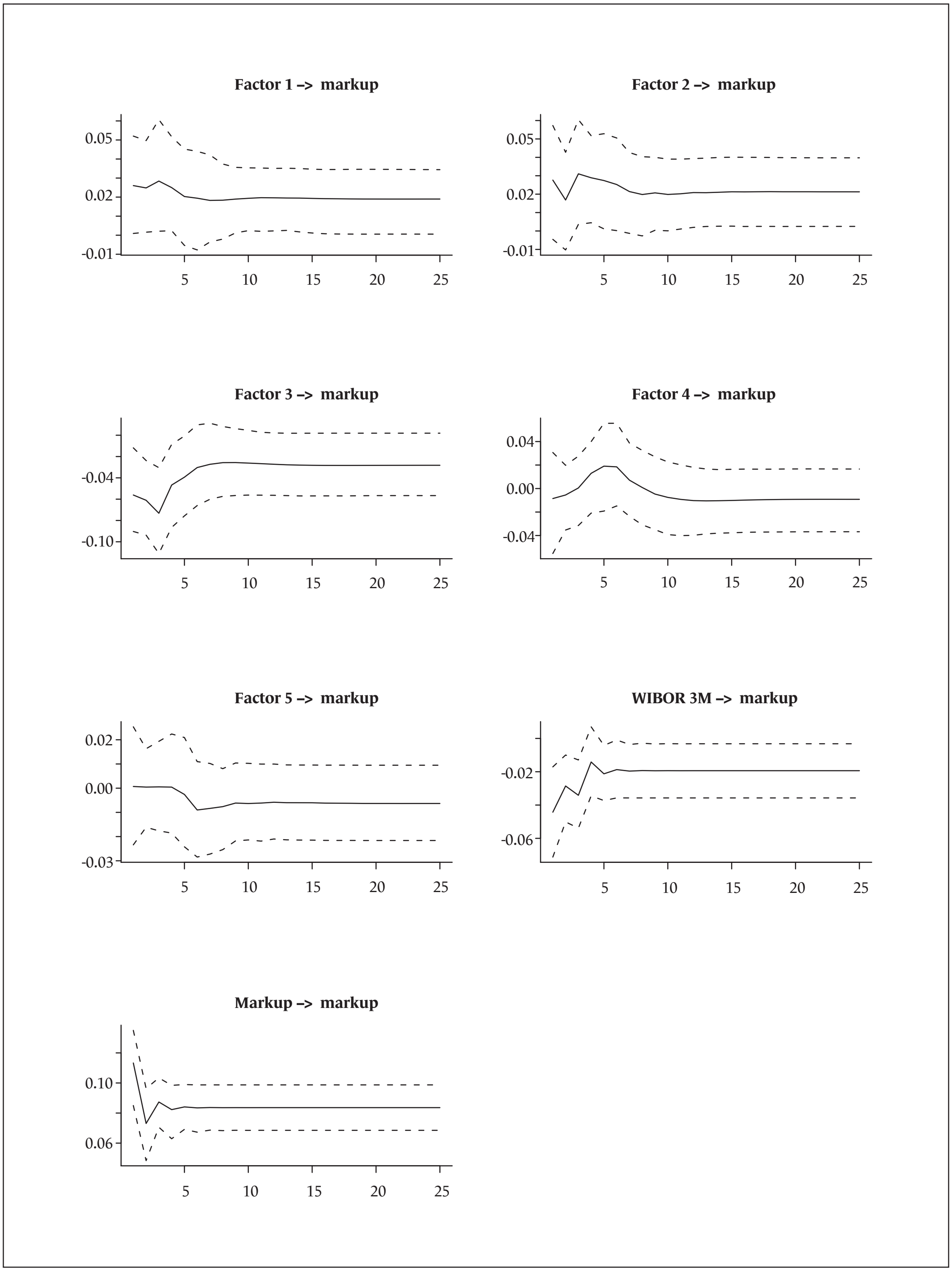

Figure 6

Cumulative orthogonalized impulse responses of WIBOR 3M