RISK SPILLOVER EFFECTS IN THE CZECH FINANCIAL MARKET

Vít Pošta

Abstract

The paper focuses on the assessment of the evolution of risk in three segments of the Czech financial market: capital market, money/debt market and foreign exchange market. First, univariate techniques are used to capture the evolution of risk in the three segments. This is carried out with the use of GARCH models. Not suprisingly, the estimated time-varying variances show possible relationships among the three segments of the financial market. The univariate analysis also shows increased risk in all three segments during the period of the world financial crisis. Then bivariate GARCH models are constructed to examine possible spillover effects between the three segments of the Czech financial market. Three bivariate GARCH models are set up to capture all possible interactions between the three segments. The analysis of the estimated coefficients in the two dimensional conditional variance equation points to the existence of relationships in terms of spillover effects among the three segments of the financial market.

Key words: financial markets, multivariate GARCH, risk spillover effects

JEL Code: G00, G01

Introduction

A natural question to ask in times of higher volatility in various segments of financial markets is: to what extent are the respective segments of aggregate financial markets interrelated? This paper addresses the issue with the use of standard univariate and multivariate methods of modelling of time-varying conditional variances and covariances.

The question is by no means novel to applied economics. One of the earliest studies by Karolyi (1995), which uses similar technical framework as will be used in this paper, focuses on returns and risk spillovers between the United States and Canada. There is a large number of similar studies, i.e. Sola et al (2002), Francis et al (2006), Morales (2008), Nekhili and Naeem (2009) or Chang et al (2010), who perform such an anlysis in case of the oil market.

Fedorova and Saleem (2010) focus on Eastern European economies in their paper, thus providing some information on the Czech economy.

Most of the studies are focused on international spillover effects typically between stock and foreign exchange markets. This paper focuses solely on a domestic financial market – financial market of the Czech economy and tries to capture possible interactions between its key segments: money market, stock market and foreign exchange market.

The paper is structured as follows: the first part makes use of univariate GARCH models to estimate time-varying volatilities of returns to stock index, exchange rate of the Czech Koruna to Euro and money market spread. The estimated time-varying variances are interpreted as measures of risk and it is shown how the risk changed during the financial crisis. The second part of the paper focuses on the interactions between the segments. Bivariate GARCH models are used to estimate possible spillover effects. The key findings are summarized in the conclusion.

1 Measures of Financial Risk

I use univariate GARCH models to estimate three measures of risk: one related to the capital market based on returns to the capital market index (PX), one related to foreign exchange market based on returns to the exchange rate of the Czech Koruna to Euro and the last one related to money market based on the spread between three-month interbank interest rate (Pribor) and the monetary policy rate: two-week repo rate set by the Czech national bank. Data were retrieved from the Czech National Bank and Patria databases and the basic sample starts in January 1996 and ends in May 2012. Daily data and logarithmic returns are used. Simple GARCH (1,1) models are used to extract the time-varying volatility of these three measures. Generally, autoregressive term is included in the mean equation. Student's t-distribution of residuals is assumed. The model is defined by:

$$y_t = \mu_1 + \mu_2 y_{t-1} + \varepsilon_t,\ \varepsilon_t \sim stt(0, h_t). \tag{1}$$

$$h_t = \omega + + \beta h_{t-1} + \alpha \varepsilon_{t-1}^2. \tag{2}$$

In equations (1) and (2): y is dependent variable, ε stands for residuals and h is conditional volatility of the residuals. Table 1 shows the basic descriptive statistics for the three series. One can see that their distribution does not follow normal distribution, which is to be expected in case of financial time-series, and all three series are stationary. Table 2 presents the results of the GARCH (1,1) estimations. No autoregressive term was used in the model of returns to CZK/EUR. The models of the capital and foreign exchange markets have very low coefficients of determination, which is to be expected according to the hypothesis of random-walk behavior of financial returns (this, of course, does not prove the hypothesis, it is just in accordance with it). However, the model for the money market spread shows high explanatory power, which is given by the fact that the two-week repo rate shows, due to its very nature, strong dependence on its past values.

Tab. 1: Descriptive Statistics

Series/Statistic	Mean	St. Deviation	Jarque-Bera	ADF
Capital Market Returns	0,0001	0,0147	21149, 05***	-45,5827***
Foreign Exchange Returns	7,0e-5	0,0045	102808,4***	-64,3518***
Money Market Spread	0,0028	0,0105	1011792***	-8,4339***

Source: own construction

Notes: Table 1 shows Jarque-Bera statistics for the null of normal distribution (*** denotes rejection of the null at 1% level of significance). Table 1 also gives t-statistic of Augmented Dickey-Fuller test under the null of a unit root (*** denotes rejection of the null at 1% level of significance). The output is based on the whole sample, i.e. daily data from 1996 to May 2012.

Tab. 2: Univariate GARCH Models

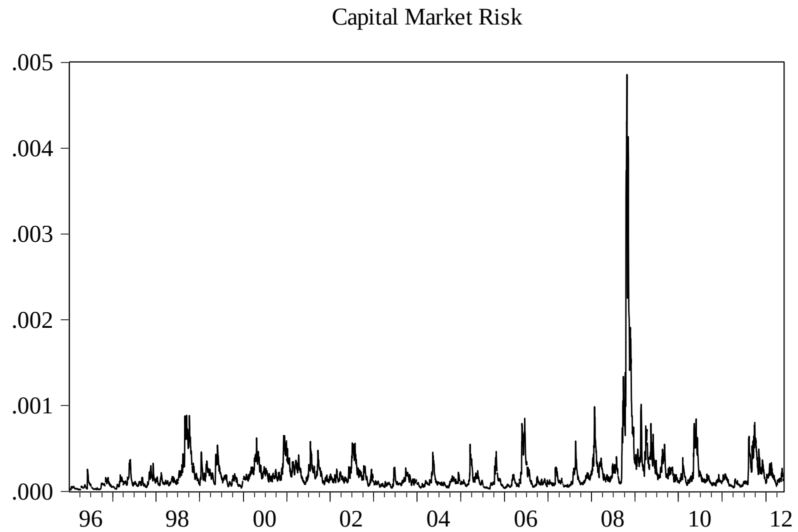
Characteristic/Model	Returns to PX Index	Returns to CZK/EUR	Money Market Spread
Variables			
μ_1	0,0008***	-0,0001***	0,0179***
μ_2	0,0825***	X	1,0007***
ω	3,0e-6***	2,0e-7***	-2,0e-10***
β	0,8651***	0,9139***	0,8052***
α	0,1266***	0,0788***	1,0659***
Model Statistics			
R^2	0,0048	0,0002	0,7205
DW	1,9950	2,0051	2,1587
ARCH LM	0,1360	0,9258	0,0144

Source: own construction

Notes: Table 2 shows estimates of GARCH (1,1) coefficients under the null that a coefficient is equal to zero (*** denotes rejection of the null at 1% level of significance). Table 2 also gives coefficients of determination (R^2), Durbin-Watson (DW) statistic and F-statistic of ARCH LM test for remaining ARCH effects in the residuals at lag 1 under the null of no remaining ARCH effects. The output is based on the whole sample, i.e. daily data from 1996 to May 2012.

Figures 1 – 4 show the conditional volatility of the residuals of the three models. This conditional volatility may be perceived as a measure of risk of the particular segment of the financial market. Clearly, one can see increased volatility in the period of the economic recession and turbulences on the world financial market in 2008 – 2009. The figure with the estimated conditional volatility of the residuals of the model of money market spread is given twice: the sample in Figure 4 starts in 2000 because when the whole sample is considered the image as seen in Figure 3 is distorted by the extremely high increase during the 1997 recession. This is also obvious in Figure 2, although the impact on the foreign exchange market was not so extreme.

Fig. 1: Measure of Capital Market Risk based on Univariate GARCH



Source: own construction

Fig. 2: Measure of Foreign Exchange Risk based on Univariate GARCH

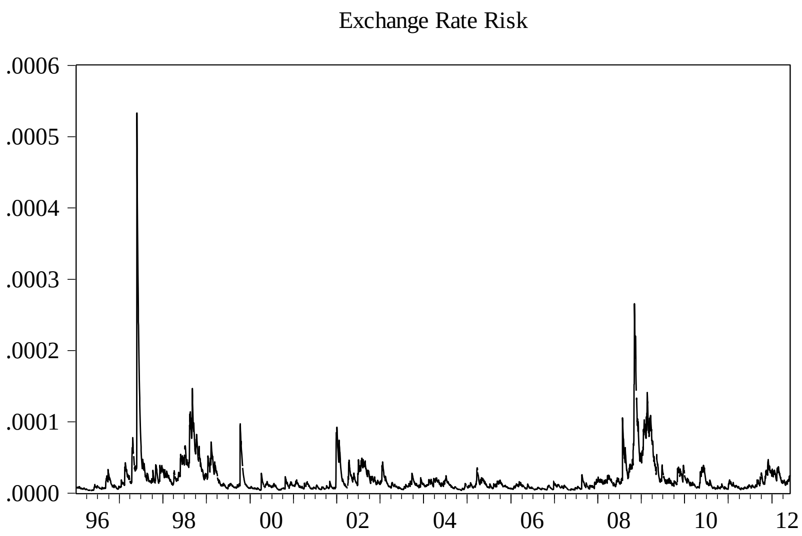


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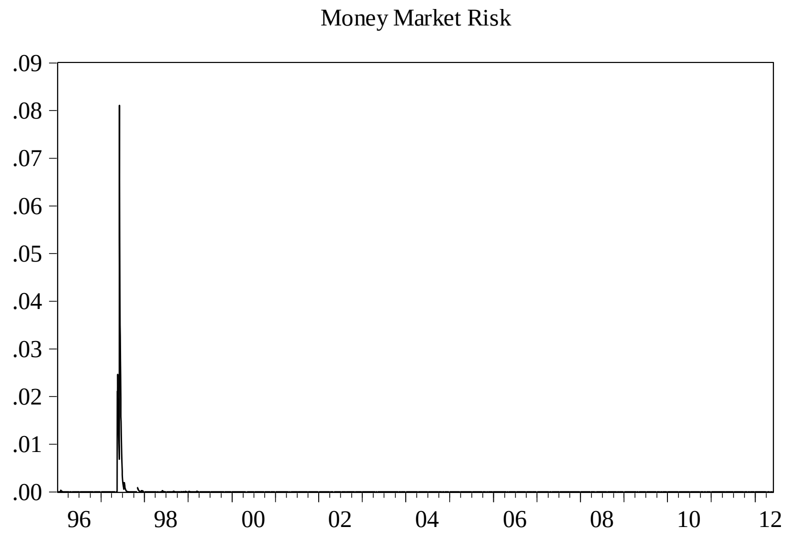
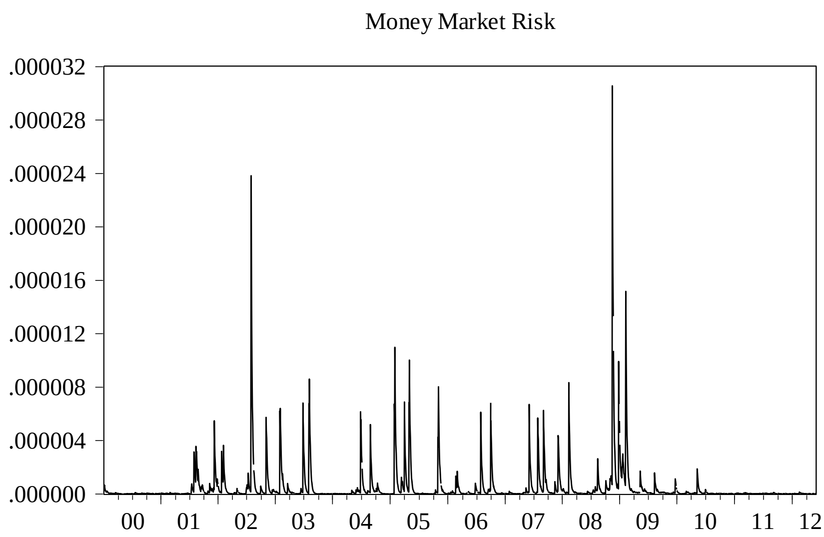
Fig. 3: Measure of Money Market Risk based on Univariate GARCH



Source: own construction

Fig. 4: Measure of Money Market Risk based on Univariate GARCH



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2 Spillover Effects

In this step of the analysis I use three bivariate GARCH models to estimate possible spillover effects between the three segments. I prefer bivariate GARCH models to trivariate as the letter requires estimation of a significantly larger number of coefficients. The sample starts in 2000 for all three models as the inclusion of the extreme behavior of the spread before 2000 causes troubles with convergence. Multivariate Student's t-distribution of the residuals is assumed. The model is defined by:

$$\mathbf{y_t} = \boldsymbol{\mu}_1 + \boldsymbol{\mu}_2 \mathbf{y}_{t-1} + \boldsymbol{\varepsilon}_t, \ \boldsymbol{\varepsilon}_t \sim stt(\mathbf{0}, \mathbf{H}_t) \tag{3}$$

$$\mathbf{H}_t = \boldsymbol{\Omega}'\boldsymbol{\Omega} + \boldsymbol{\beta}'\mathbf{H}_{t-1}\boldsymbol{\beta} + \boldsymbol{\alpha}'\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}_{t-1}'\boldsymbol{\alpha}. \tag{4}$$

Here ***y*** is a vector of dependent variable, ***ε*** is a vector of residuals, ***H*** is a conditional variance-covariance matrix, ***Ω*** is a lower triangular matrix of constants, ***β*** and ***α*** are matrices of coefficients and ***μs*** are vectors of coefficients. Figures 5 – 7 present the estimates of time-varying variances of the residuals and also covariances between the residuals. The results show both increased volatility in the three segments of the financial market, which was already shown in the previous part, and increased linear relation between the variables as captured by the covariances. Due to limited space I present just the necessary output to analyze the spillover effects. This is presented by equations (5) to (7), which are the estimates of equation (4).

Fig. 5: Capital Market and Foreign Exchange Risk based on Bivariate GARCH

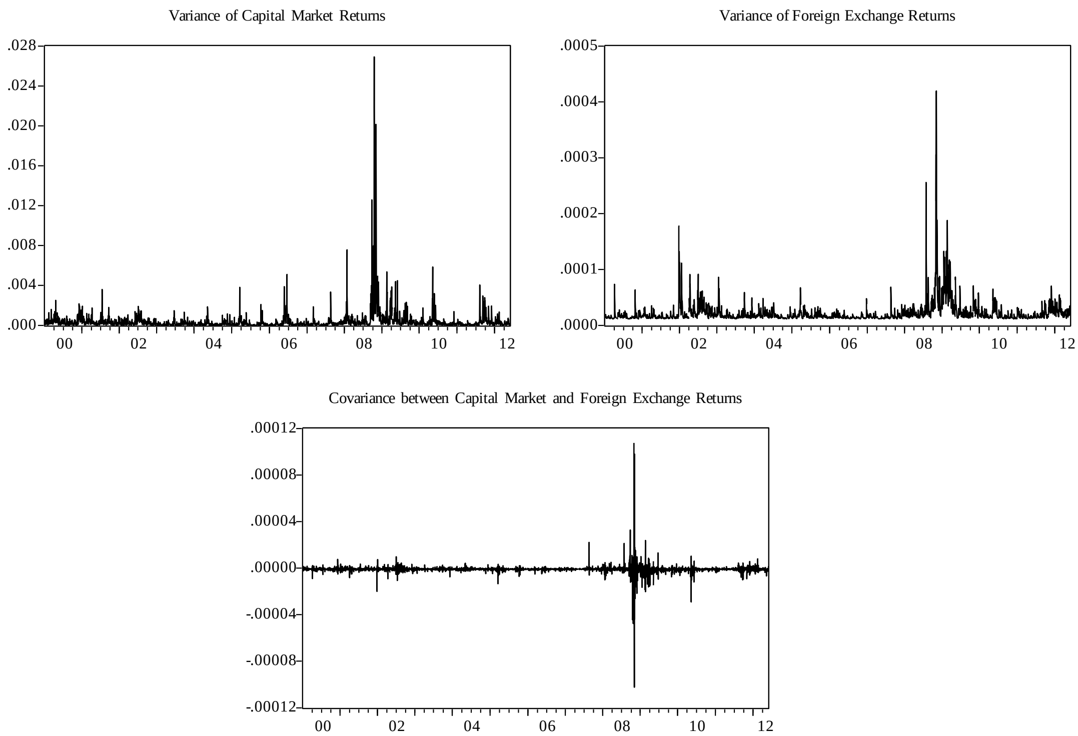

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Fig. 6: Capital Market and Money Market Risk based on Bivariate GARCH

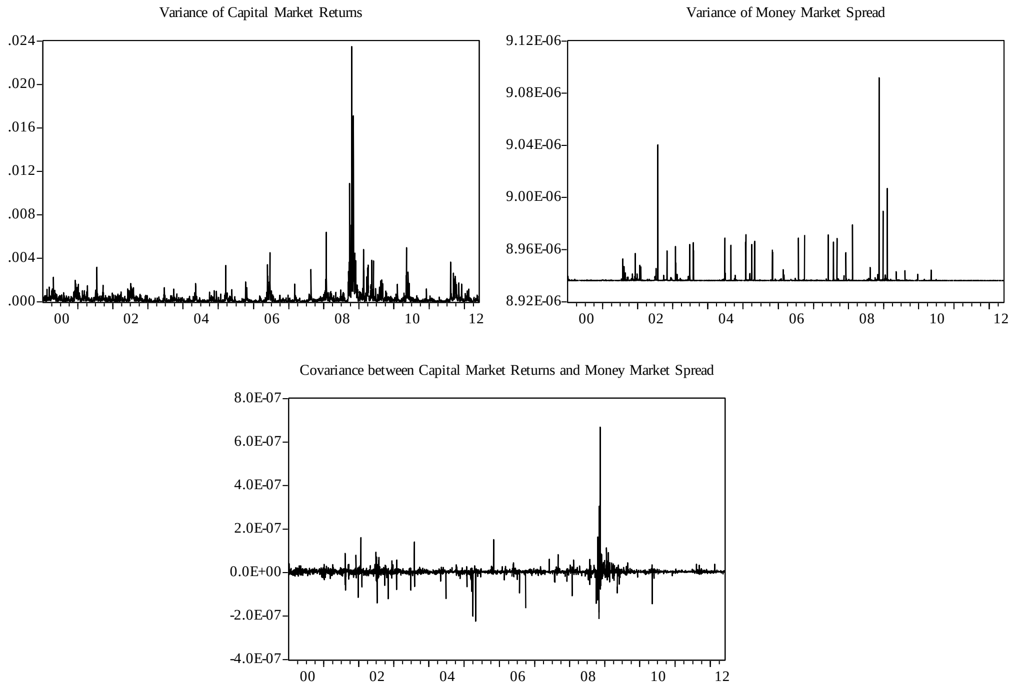

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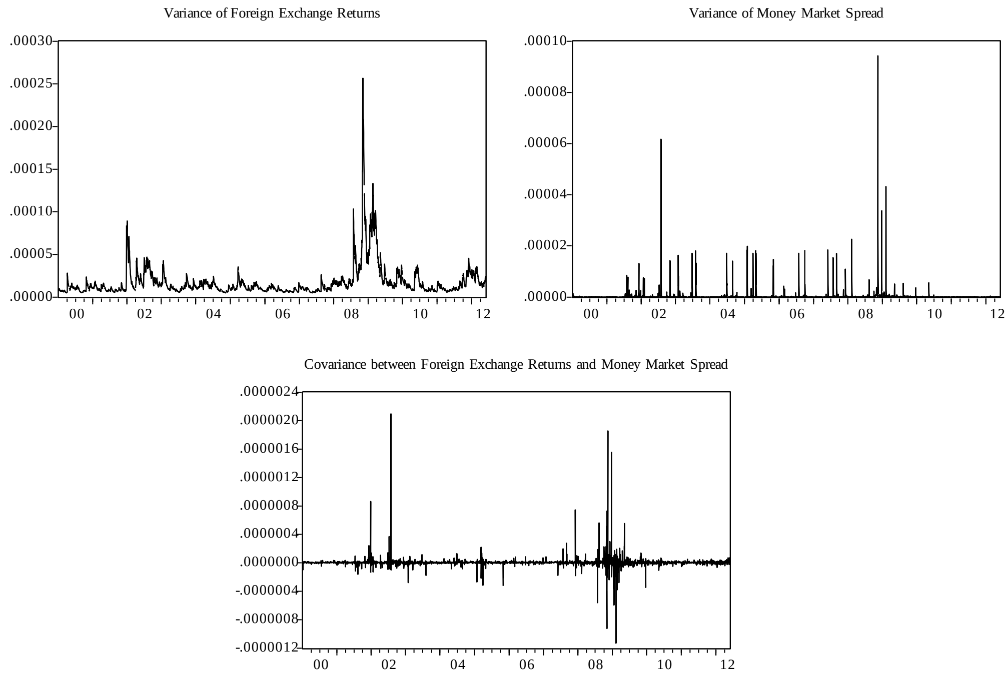
Fig. 7: Foreign Exchange and Money Market Risk based on Bivariate GARCH



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Eq. 5-7: Estimates of the Variance Equation of the Bivariate GARCH Models

$$\mathbf{H_t} = \begin{pmatrix} -0{,}0006* & 0 \\ 0{,}0021 & 0{,}0001* \end{pmatrix}' \mathbf{\Omega} + \\ + \begin{pmatrix} 0{,}1472** & 0{,}6091* \\ 0{,}2948 & -0{,}7257** \end{pmatrix}' \mathbf{H_{t-1}\beta} + \begin{pmatrix} 0{,}8638** & 0{,}5041* \\ -0{,}2235* & 0{,}4364** \end{pmatrix}' \boldsymbol{\varepsilon_{t-1}\varepsilon'_{t-1}\alpha}, \qquad (5)$$

$$\mathbf{H_t} = \begin{pmatrix} -0{,}0002* & 0 \\ 0{,}4353* & 0{,}0030* \end{pmatrix}' \mathbf{\Omega} + \\ + \begin{pmatrix} 0{,}1287** & 0{,}6054* \\ -0{,}1167* & -0{,}0030* \end{pmatrix}' \mathbf{H_{t-1}\beta} + \begin{pmatrix} 0{,}8274** & 0{,}4353* \\ -0{,}0301* & 0{,}0664* \end{pmatrix}' \boldsymbol{\varepsilon_{t-1}\varepsilon'_{t-1}\alpha}, \qquad (6)$$

$$\mathbf{H_t} = \begin{pmatrix} -0{,}0006* & 0 \\ -0{,}0000 & -0{,}0001* \end{pmatrix}' \mathbf{\Omega} + \\ + \begin{pmatrix} 0{,}5064** & 0{,}7991* \\ 0{,}3902 & -0{,}3386* \end{pmatrix}' \mathbf{H_{t-1}\beta} + \begin{pmatrix} 0{,}2588** & 0{,}1361* \\ -0{,}6914* & 1{,}6028** \end{pmatrix}' \boldsymbol{\varepsilon_{t-1}\varepsilon'_{t-1}\alpha}. \qquad (7)$$

Source: own construction

Notes: Equation (5) relates to bivariate GARCH between returns to capital market and returns to foreign exchange market. Equation (6) relates to bivariate GARCH between returns to capital market and money market spread. Equation (7) relates to bivariate GARCH between returns to foreign exchange market and money market spread. (*,** shows rejection of the null that a coefficient is equal to zero at 10 % and 5 % level, respectively)

The estimates show that the own GARCH and ARCH effects (dependence of variance on lagged variance and innovations) are a little stronger in cases of capital and foreign exchange markets as compared with the money market. The spillover effects are present at 10 % level of significance and they typically run both ways with just two exceptions.

Conclusion

The presented paper dealt with measuring risk in financial markets. First, univariate GARCH models for three segments of the financial market were used. The three segments were: capital market, foreign exchange market and money market. Using univariate GARCH models one can extract conditional time-varying volatility of the residuals, which may be viewed as a measure of risk in this context. The results presented in the paper were in line with economic intuition.

The second part of the paper used bivariate GARCH models to estimate not only conditional variances of the residuals but also conditional covariances between them. This can be used to analyze possible spillover effects between the three segments. Bivariate GARCH models were preferred to those including more dependent variables as those models require a lot more coefficients to estimate. The results in terms of time-varying variances and covariances of and between the residuals were again in line with economic intuition. The results also pointed to the existence of spillover effects between the three segments.

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Contact

Vít Pošta

University of Economics, Prague

W. Churchill sq 4, Prague, 13067

Vit.Posta@vse.cz