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ON THE CAUSAL RELATIONSHIPS BETWEEN MONETARY, FINANCIAL AND REAL MACROECONOMIC VARIABLES: EVIDENCE FROM CENTRAL AND EASTERN EUROPE

Abstract. *The paper investigates the dynamic links between macroeconomic variables in countries from Central and Eastern Europe over January 1998 to September 2007. The research employs cointegration, Granger causality tests and innovation accounting techniques in order to capture the relationship between stock prices and gross domestic product, consumer price index, money supply, interest rates and real exchange rates. The signs of variables in the cointegrating vectors are consistent with economic reasoning: the consumer price index is positively related to stock prices, while the real exchange rate exhibits an opposite behaviour, except for Romania. Real interest rates in Czech Republic, Poland and Romania are positively correlated with stock prices, which may be cautiously interpreted as a lack of liquidity in financial markets. The impulse response analysis points towards a number of similarities among these countries: shocks in macroeconomic variables generate innovations in stock prices over the short-run; the responses of stock prices to shocks in themselves are negative over the short-run and positive, except for Romania, over the long-run; shocks in GDP determine positive responses of stock prices in all countries.*

Keywords*: Central and Eastern Europe, stock prices, macroeconomic variables, cointegration, Granger causality, innovation accounting techniques*

JEL Classification: F30, G10

1. Theoretical considerations

More recently, a considerable amount of research has been dedicated to the study of the interrelationships between real goods, money and securities markets in an economy. This research uses advanced econometric models such as bivariate and multivariate cointegration, innovation accounting techniques, Granger causality tests and GARCH models to study the dynamic, bi-directional, bi- or multivariate relation between macroeconomic variables. One important subject that has received attention in the recent past refers to linkages between stock prices and macroeconomic variables. Macroeconomic evolutions may have systematic influences on stock prices through their influences on expected future cash flows, as the stock valuation model suggests. Linkages between macroeconomic variables and stock prices may also be understood in the framework of the arbitrage pricing theory (APT) model developed by Ross (1976). At the same time, Friedman (1988) and Mishkin (2007) use the standard aggregate demand and supply framework to

explain the role of equities markets in the specification of money demand and in the monetary transmission mechanism, respectively. These models offer a foundation for the understanding of long-run versus short-run interactions among macroeconomic variables.

The majority of empirical studies in this field have tackled the developed economies, such as Fama (1990), Burbridge and Harrison (1985), Chen et al. (1986), Asprem (1989), Lee (1992), Kaneko and Lee (1995), Haung et al. (1996), Darrat and Dickens (1999), Gjerde and Saettem (1999), Kim (2003), and Merikas and Merika (2006). The case of emerging markets is less approached, just a couple of studies examining mostly the developing markets from South-East Asia. Doong et. al (2005) examine six emerging Asian countries over 1989 and 2003 and find no cointegration between their exchange rates and stock prices, but they detected bi-directional causality in Indonesia, Korea, Malaysia and Thailand. Ibrahim (2000) studies the interactions between the foreign exchange market and the stock market in Malaysia and his results indicate that despite the lack of a long-run relationship between the exchange rate measures and stock prices in bivariate cointegration models, there is evidence of such long-run relations in multivariate models that include money supply and foreign reserves. Ibrahim and Aziz (2003) find that, in Malaysia, the exchange rate is negatively associated with the stock prices, while the money supply generates immediate positive liquidity effects and negative long-run effects on the stock prices. Murinde and Poshakwale (2004) investigate price interactions between the foreign exchange market and the stock market in a number of three European emerging financial markets – Hungary, Poland and Czech Republic – before and after the adoption of the euro. Using daily observations on both stock prices and exchange rates, they find that for the pre-euro period stock prices in these countries uni-directionally Granger cause exchange rates only in Hungary, while bi-directional causality relations exist in Poland and Czech Republic. After the euro adoption, exchange rates uni-directionally Granger-cause stock prices in all three countries. Wongbangpo and Sharma (2002) investigate the long and short-term relationships of a number of macroeconomic variables – GNP, consumer price index, money supply, interest rate, exchange rate – with the stock prices in five ASEAN countries and find that stock prices interact with key macroeconomic variables. This makes them reach the conclusion that decent government economic or financial policies can yield impressive gains in both the sectors. Hondroyiannis and Papapetrou (2001) study the case of Greece, considering macroeconomic variables such as industrial production, interest rates, exchange rates, stock returns, the performance of international markets and oil price, and find that stock returns do not lead changes in real economic activity, while the macroeconomic activity and foreign stock market performance explain only partially Greek stock prices movements. At the same time, for an oil dependent economy such as Greece, they find that oil price changes are able to explain stock price movements and have a negative influence on macroeconomic activity in general.

Our paper contributes to the debate on the linkages between the stock market and macroeconomic variables in the case of emerging markets, with a direct application to Central and Eastern European countries. The issues we address refer to stock return predictability, transmission mechanisms of macroeconomic performance to stock market performance, and the short-run versus long-run stability of macroeconomic variables interactions. The research is developed in the following directions. First, we analyse the issue in a multivariate setting using macroeconomic variables that capture evolutions from real goods market, money market and securities markets. Second, we use the standard procedures of cointegration and vector autoregressions (VARs), coupled with innovation accounting techniques – specifically, impulse response functions and variance decomposition – in order to investigate the long-term versus the short-term dynamic of the links among macroeconomic variables. These techniques allow, at the same time, to discover the direct and indirect effects of innovations in variables that are of interest for the changes in the other variables. The variance decomposition shows the contribution of a variable's forecast error variance to the forecast error variance of another variable, while the impulse response functions capture the intensity and the direction of the response in one variable to shocks in another variable, the latter being defined as a one standard deviation shock. Third, we investigate the possibility that stock prices cause macroeconomic variables in a Granger sense or that they are Granger-caused by macroeconomic variables.

The current research builds upon previous work on the interactions among macroeconomic variables in Romania conducted by Dumitrescu and Horobet (2009. We extend in the current paper the analysis in four main directions. First, we expand the set of macroeconomic variables by including a measure of real output – gross domestic product – and the consumer price index, thus taking into account variables that are specific to the real goods markets. Second, we include in our model two exogenous variables – the performance of international securities markets and the evolutions on international commodities markets –, aiming at an improved explanation of the linkages between variables. Third, we add an analysis of the causal relationships among macroeconomic variables, employing Granger causality tests. Fourth, we contrast the Romanian framework against the specificities of other Central and Eastern European markets – Czech Republic, Hungary and Poland – in order to investigate similarities and differences between them in terms of macroeconomic dynamics, which are supportive for a better understanding of the economic convergence process in the region, as result of European Union membership for these countries.

2. The hypothesized model

The basis for our model is the interrelationship among macroeconomic variables, of which relevant for our analysis are the goods markets, the money market and the securities market. The goods market variables considered are the gross domestic product (GDP) and the consumer price index (CPI). The money market variables are the money supply and the nominal interest rate. The securities market is

represented by a stock price index. The model also includes an external competitiveness measure – represented by the real effective exchange rate of the domestic currency. We investigate the long and short run relationship between the stock market (SP) and the foreign exchange market (FXM), by taking into account influences from the gross domestic product (GDP), consumer price index (CPI), money supply (MS), interest rates (IR), considering the following general model:

$$X_t = (SP_t, GDP_t, CPI_t, FXM_t, MS_t, IR_t).$$

We hypothesize a positive relation between stock prices and GDP, as the level of real economic activity will positively impact corporate profitability through the increase in output reflected by increases in cash flows and, as result, stock prices will raise. The opposite effect would take place in a recession, when decreases in the level of real economic activity will most likely lead to a decline in corporate profitability and to lower stock prices. This positive relation is empirically observed by Geske and Roll (1983), Fama (1990), and Mukherjee and Naka (1995) for developed countries, and by Ibrahim (2000), Handroyiannis and Papapetrou (2001), Wongbangpo and Sharma (2002), and Ibrahim and Aziz (2003) for emerging countries.

We hypothesize a positive relation between the nominal exchange rate and the stock price, since both exchange rate levels and changes in exchange rates affect the performance of a stock market, as indicated by Solnik (1987), Soenen and Hennigar (1988), Ma and Kao (1990) and Mukherjee and Naka (1995). For what concerns the relation between the stock prices and the real exchange rate, we also hypothesize it as being positive, as an increase in the competitiveness level of a country should be reflected by better performances of domestic companies and higher stock prices.

Regarding the relationship between stock prices and money supply, it can be either positive or negative. Ceteris paribus, an increase in the money supply generates an excess supply of money and, consequently, an excess demand for equity, which results in higher stock prices. However, a negative effect of the money supply on stock prices is also conceivable through positive inflationary effects and portfolio substitution effects: a change in the money supply causes changes in the equilibrium position of money in relation to other assets in the portfolio, altering the demand for other assets that compete with money balances. Empirical evidences on the link between money supply and stock prices are rather mixed: Mukherjee and Naka (1995) find a positive long-run relation for Japan, Maysami and Koh (2000) for Singapore, while Ibrahim and Aziz (2003) identify a negative relationship for Malaysia.

We hypothesize a negative relation between nominal interest rates and stock prices, as the volatility of interest rates is definitely critical for the asset pricing. The standard economic argument resides on the discount rate used to calculate the present value of assets: an increase in the interest rate is seen as raising the required rate of return, which adversely affects the asset's present value (its current price). When the nominal interest rate is seen as an opportunity cost, it will affect investors' decisions regarding their asset holdings, since an increase in the

opportunity cost will determine them to substitute equity for other assets in their portfolios. Therefore, an increase in interest rates has a negative effect on stock prices from the perspective of asset portfolio allocation. At the same time, as higher interest rates may cause recession and declines in future corporate profitability, the relation between them and stock prices is again negative. As constituents of the nominal interest rate, inflation and real interest rate are hypothesized to have also a positive relation to stock returns and a negative relation to stock prices: when inflation and/or real interest rates increase, risk premiums increase and are reflected in higher returns and lower stock prices.

In addition to these macroeconomic variables, the model includes two exogenous variables that capture the external influences on the dynamic links between domestic variables. The performance of the foreign stock markets is used in order to measure the influence of international stock market performance in domestic stock returns, and the international price of oil explains the influence of international commodities markets on domestic performances.

3. Data

The study focuses on four European Union members from Central and Eastern Europe: The Czech Republic, Hungary, Poland and Romania. The empirical analysis has been carried out on quarterly data for the period 1998:1 to 2007:3. To explain the dynamic interactions among real stock returns, oil prices and economic activity, a VAR analysis is performed. The VAR model includes six endogenous and two exogenous variables. For each economy under consideration, the endogenous set comprises time series of macroeconomic indicators that measure the evolutions of the goods, money, financial and foreign exchange markets. According to Walras' law, the sum of excess demand of all markets will equal zero, whether or not the economy is in equilibrium. Since quantitative analysis rewards parsimony, and following the literature on the analysis of securities markets, we have premeditatedly excluded from the model labour market variables. The goods market is represented by the real gross domestic product (RGDP), which is the nominal gross domestic product deflated by the consumer price index, and the consumer price index (CPI). Money market variables include the real interest rate (RINT), which is the 12-month rate adjusted for inflation, and the money supply (M1). The influence of the capital market evolution enters the model through the stock market index (RINDEX), adjusted for inflation, while the foreign exchange market is represented by the real effective exchange rate, reflecting the evolution of one country's currency against those of its principal 27 trading partners (REER27).

We hypothesised that all four economies are open and therefore prone to external influences, whether positive or negative. However, the existing literature on financial markets contagion indicates that negative shocks are transmitted more rapidly across interdependent economies, and their immediate effects appear more evident. Moreover, recent developments in commodities markets suggest that the high volatility of commodities prices, especially for oil, may affect globalized

economies at all levels. For this reason, we included in the model two measures of these external influences: the real foreign stock price (RSP500) is the S&P 500 New York stock market index adjusted for inflation, and the real oil price (ROIL_EU) is the European Union (EU27) consumer price index for liquid fuels deflated by the European Union (EU27) consumer price index. All variables, except the stock indexes, the interest rates and the foreign exchange rate, were seasonally adjusted. Data on macroeconomic variables were collected from the Eurostat and OECD databases. Hungarian, Polish and Czech stock indexes series were downloaded from the MSCI historical database. The Romanian stock market index data was collected from the Romanian Stock Exchange website.

4. Empirical results

4.1. Unit root tests

We use three traditional unit root tests, namely the augmented Dickey–Fuller (ADF) test, the Phillips–Perron (PP) test and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test to investigate the *I*(1) property. All tests fail to reject the null hypothesis of the existence of a unit root in log levels but reject the same null hypothesis in the log first difference of the series. Thus, all variables used in this study are integrated of order 1, or I(1).

4.2. Multivariate cointegration

Of the many possible tests for detecting cointegration, the most general is the multivariate test based on the autoregressive representation discussed in Johansen (1988) and Johansen and Juselius (1990). This procedure provides more robust results when there are more than two variables (Gonzalo, 1994). The Johansen approach considers a vector of *n* potentially endogenous variables

$$\Delta Y_t = \mu + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Pi X_{t-k} + Bx_t + \varepsilon_t \quad (2)$$

where the Π matrix incorporates the long-run relationship(s) in the data. When $0 <$ rank(Π) $= r < n$, Π can be written $\Pi = \alpha\beta'$ where α represents the speed of adjustment to disequilibrium and β' is interpreted as a $n \times r$ matrix of cointegrating vectors. The vector of constants μ in (2) signals the possibility of deterministic drift in the data. The Johansen method provides two different likelihood ratio tests, the trace test and the maximum eigenvalue test, to determine the number of cointegrating vectors (Hendry and Juselius, 2000).

Because the Johansen tests are known to be sensitive to the lag selection, we select the optimal lag length based on several different criteria. These criteria include the sequentially modified Likelihood–Ratio (LR) test, Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan–Quinn Information Criterion (HQ). Thus, we identify lag lengths of 1 for The Czech Republic and Romania and 3 for Hungary and Poland. The restriction imposed by the relatively small number of observations and the complexity of the model did not allow testing for lags of higher order.

Johansen (1992) derives a systematic test procedure for the model specification that examines both the rank order and the deterministic component for the cointegrating system simultaneously. The trace statistic tests the null hypothesis of r cointegrating relations against the alternative of k cointegrating relations, for r = 0,1,2,…,k-1. To establish the number of cointegrating relations r conditional on the assumptions made about the trend, we proceed sequentially from r = 0 to r = 4 (k – 1) until we fail to reject the null hypothesis. The λ_{trace} statistics are reported in Table 1. The data for The Czech Republic and Hungary allows for linear deterministic trend in data, with an intercept (and no trend) restricted to the cointegrating space. In contrast, data for Poland and Romania are best fitted using a long-run model that allows for quadratic deterministic trend in the data, with an intercept and trend in the cointegrating equation.

Table 1. Tests for deterministic components in the cointegration model

Null	The Czech Republic (1)						Hungary (3)					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
r = 0	157.93	**	188.21	**	166.76	**	321.63	**	411.56	**	364.45	**
r = 1	104.35	**	126.74	**	106.06	**	178.99	**	266.11	**	219.07	**
r = 2	65.12	**	84.75	**	64.39	**	94.27	**	150.17	**	107.10	**
r = 3	36.61	*	51.43	**	31.52	**	45.99	**	65.48	**	26.72	
r = 4	16.99		23.30		8.85		17.13	*	24.72		6.67	
r = 5	0.21		4.90		0.65		0.66		4.91		1.75	
	Poland (3)						Romania (1)					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
r = 0	265.93	**	402.35	**	379.87	**	149.92	**	174.66	**	149.26	**
r = 1	136.71	**	256.46	**	240.15	**	86.73	**	103.69	**	79.34	*
r = 2	79.70	**	131.22	**	115.44	**	49.22	*	66.15	*	45.28	
r = 3	44.49	**	78.19	**	69.26	**	25.82		33.20		25.58	
r = 4	10.08		43.26	**	34.41	**	10.28		17.61		11.97	
r = 5	0.00		9.68		3.12		1.59		5.12		3.26	

Note: Model 1: an intercept is restricted to the cointegrating space (the long run model); Model 2: deterministic trends in the levels and no intercept in the cointegrating vectors; Model 3: model with a linear trend in the cointegration vectors. The numbers in parenthesis are the lag lengths selected by the LR test. The test procedure is to go from (1) to (3). At each stage, the λ_{trace} test statistic is compared to its critical value. The deterministic component is then determined where the null hypothesis is not rejected for the first time. Critical values are obtained from Osterwald-Lenum (1992). * and ** denote rejection of the hypothesis at the 5%, 1% level, respectively.

The λ_{max} and λ_{trace} statistics are presented in Table 2. Theoretically, the λ_{trace} statistics tend to have higher power than λ_{max}, since they take into account all (n – r) of the smallest eigenvalues. Therefore, we observe at the 5% level of significance, five cointegrating vectors for The Czech Republic, four for Poland, three for Hungary and only two for Romania. The Lagrange Multiplier test statistics for correlation among residuals indicate no serial correlation among residuals up to lag 4.

Table 2. Tests for the number of cointegrating vectors in selected models

Null	Deterministic series: constant restricted to cointegrating space (or model 1)									
	The Czech Republic (1)					Poland (3)				
	Eigenvalue	Test statistics				Eigenvalue	Test statistics			
		λ_{max}		λ_{trace}			λ_{max}		λ_{trace}	
r = 0	0.77	53.58	**	157.93	**	0.98	129.23	**	265.93	**
r = 1	0.65	39.23	**	104.35	**	0.80	57.01	**	136.71	**
r = 2	0.54	28.51	*	65.12	**	0.63	35.21	**	79.70	**
r = 3	0.41	19.62		36.61	**	0.63	34.41	**	44.49	**
r = 4	0.36	16.78	*	16.99	*	0.25	10.08		10.08	
r = 5	0.01	0.21		0.21		0.00	0.00		0.00	
	Deterministic series: liniar trend in the cointegration vectors (or model 3)									
	Hungary (3)					Romania (1)				
	Eigenvalue	Test statistics				Eigenvalue	Test statistics			
		λ_{max}		λ_{trace}			λ_{max}		λ_{trace}	
r = 0	0.98	145.38	**	364.45	**	0.85	69.92	**	149.26	**
r = 1	0.96	111.97	**	219.07	**	0.60	34.06		79.34	*
r = 2	0.90	80.38	**	107.10	**	0.41	19.71		45.28	
r = 3	0.44	20.05		26.72		0.31	13.60		25.58	
r = 4	0.13	4.91		6.67		0.21	8.71		11.97	
r = 5	0.05	1.75		1.75		0.08	3.26		3.26	

Note: The numbers in parenthesis are the lag lengths selected by likelihood ratio test. The deterministic term included in the model is statistically selected by the procedure suggested by Johansen (1992). Critical values are obtained from Osterwald-Lenum (1992). * and ** denote rejection of the hypothesis at the 5%, 1% level, respectively.

Johansen and Juselius (1990) noted that the first cointegrating vector corresponding to the largest eigenvalues is the most correlated with the stationary part of the model, and hence the most useful. After normalizing the coefficients of stock price indices to one, the restricted long run relationship between stock prices and macroeconomic variables can be expressed as (t-statistics are reported in parenthesis):

The Czech Republic:

RINDEX	=	– 8.29 (-4.61)	+	*RGDP* 13.88 (6.67)	+	*CPI* 2.86 (3.74)	+	*M1* 0.54 (9.06)	–	*RINT* 5.59 (-4.26)	+	*REER27* 3	54.4

Hungary:

RINDEX	=	– 2.62 (-2.35)	+	*RGDP* 10.7 (16.35)	–	*CPI* 3.28 (-7.16)	–	*M1* 1.07 (-9.66)	–	*RINT* 6.92 (-12.11)	+	*REER27* 1	32.3

Poland:											
RINDEX	= 3.54	+	5.12	–	1.76	+	0.38	–	1.64	–	*REER27* 56.66
	(1.49)		(2.51)		(-3.21)		(1.99)		(-3.81)		
Romania:											
RINDEX	= 3.42	+	2.94	–	0.95	+	0.10	+	3.43	–	*REER27* 64.64
	(3.78)		(9.23)		(-3.48)		(1.50)		(9.95)		

The signs of the coefficients in the VEC equations appear to be consistent across countries. There is a positive relation between real GDP and the stock index in Hungary and The Czech Republic, while the opposite holds for Poland and Romania. An increase in the consumer price index has led to an increase in the stock market index, for all countries during the period analyzed. The real interest rate is positively correlated with stock prices for three countries – Czech Republic, Poland and Romania – and negatively correlated with stock prices in Hungary. Except for Romania, an increase in the real exchange rate translated into a decrease of stock market prices in all other countries.

4.3. Causality tests

In a cointegrated set of variables, Granger (1988) suggests that the short-term causal relations between these variables should be examined within the framework of the vector error correction model. The system of the short run dynamic of the stock price series can be written as:

$$\Delta RINDEX_t = \alpha_1 + \beta_1 EC_{t-1} + \sum_{i=1}^{K} \delta_{1i} \Delta RINDEX_{t-i} + \sum_{i=1}^{K} \theta_{1i} \Delta RGDP_{t-i} + \sum_{i=1}^{K} \xi_{1i} \Delta CPI_{t-i} + \sum_{i=1}^{K} \rho_{1i} \Delta M1_{t-i} + \sum_{i=1}^{K} \omega_{1i} \Delta RINT_{t-i} + \sum_{i=1}^{K} \tau_{1i} \Delta REER27_{t-i} + \varepsilon_t^{RINDEX},$$

where:

K - number of lags

ε_t^{RINDEX} - stationary random processes with mean 0 and constant variance

$\beta, \delta, \theta, \xi, \rho, \omega, \tau$ - parameters to be estimated

EC_{t-1} - error correction term obtained from the cointegration vector

There are two channels by which causality can be detected (Granger, 1988): for example, stock prices are Granger-caused by real GDP if either θ_{1i} are jointly significant, or the error term coefficient β_1 is significant. F-statistic is used to test the joint significance of the lags of each variable, while t-statistic tests the

coefficient of the lagged error correction term. Table 4 presents the qualitative causal relations[1].

Table 4. Causal relations between stock prices and macroeconomic variables

Country	RGDP → RINDEX	CPI → RINDEX	M1 → RINDEX	RINT → RINDEX	REER27 → RINDEX
Czech Republic	Yes	Yes	Yes	No	No
Hungary	Yes	No	No	No	No
Poland	No	Yes	Yes	No	Yes
Romania	Yes	Yes	Yes	Yes	No
	RINDEX → RGDP	RINDEX → CPI	RINDEX → M1	RINDEX → RINT	RINDEX → REER27
Czech Republic	No	Yes	No	No	Yes
Hungary	No	No	No	No	No
Poland	No	No	No	No	Yes
Romania	No	Yes	No	Yes	No

The results of the Granger tests show that macroeconomic variables represent significant sources of information for the current values of stock prices in all four countries, but the specific variables that offer such information from their past values are different from one country to the other. In Czech Republic, stock prices are Granger-caused by GDP, consumer price index and money supply; in Hungary, Granger-causality of stock prices comes only from GDP; for Poland, stock prices are Granger-caused by the consumer price index, money supply and exchange rate; Romanian stock prices are Granger-caused by all macroeconomic variables except for the exchange rate. We also investigate the predictive ability of stock prices over macroeconomic variables. The results are shown in the lower part of Table 4. As one may observe, stock prices Granger-cause only three variables: the consumer price index in Czech Republic and Romania, the interest rate in Romania, and the exchange rate in the Czech Republic and Hungary. At the same time, the F-statistics indicate that lagged values of GDP are significant for the stock price equations in Hungary, and that lagged values of the consumer price index and money supply are significant in the case of Romania. For what concerns causality from stock prices to macroeconomic variables, F-statistics show that lagged values of stock prices are significant only for the exchange rate and in the case of Romania. These results indicate, in our view, that evolutions on the real goods and money markets are reflected in the performance of the stock market and past values of some macroeconomic variables may be used to forecast future values of stock prices. On the opposite side, past and current values of stock prices do not seem to

[1] The quantitative results are available from authors upon request.

contain information that is able to improve the forecasts for macroeconomic variables in all four countries.

4.4. Innovation accounting techniques

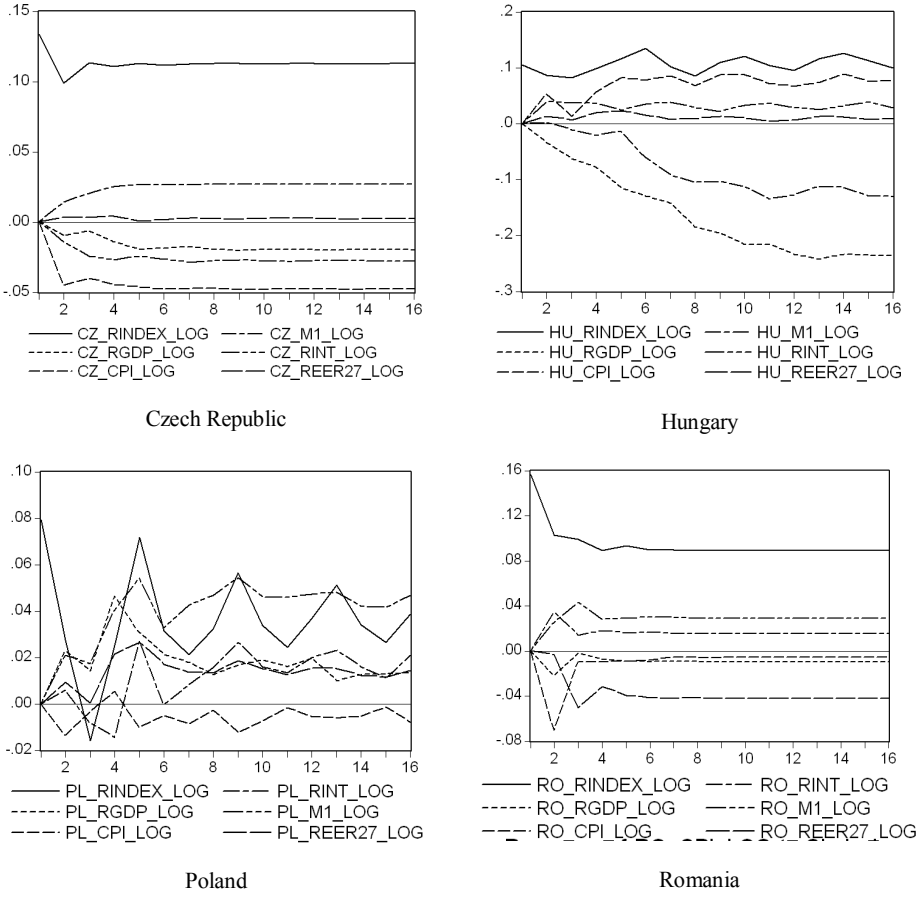
Innovation accounting techniques have been proposed by Litterman (1979) and aim at analysing the short-run dynamics among variables, using impulse response functions and variance decomposition. Impulse response functions are employed to trace out the dynamic interaction among variables as it shows the dynamic response of all the variables in the system to a shock or innovation in each variable. We implement impulse response functions and variance decomposition in a VECM framework, using the variable in levels. Generally, two different ways of specifying a VAR when the time series are cointegrated may be applied: an unrestricted VAR in levels or a VECM. The appropriateness of each of the ways remains still under debate in the literature, as current findings offer unclear evidence for a better performance of a VECM as compared to an unrestricted VAR for all forecasting horizons. Naka and Tufte (1997) find that the two methods have comparable performance at short horizons, while Clements and Hendry (1995), Engle and Yoo (1987) and Hoffman and Rasche (1996) offer support in favour of the unrestricted VAR.

Figure 1 shows the results of our impulse response analysis conducted over a horizon of four years for each of the countries considered. Specifically, it presents the response of stock prices to shocks in the macroeconomic variables. For Czech Republic, stock prices react negatively over the short-run (up to three or four quarters) to shocks in GDP, consumer price index, interest rates, and themselves, but the response diminishes in intensity in time. For two macroeconomic variables – the real exchange rate and the money supply – the short-run response of stock prices is positive, but it also stabilizes over the longer run. Over all forecast horizons, the highest response of stock prices is present to a shock in themselves, while the lowest responses vary. After the first quarter, shocks in other variables to do generate shocks in stock prices, after a year the real exchange rate shock produces the lowest response of stock prices, while over an eight and sixteen quarters horizons innovations in interest rates engender the smallest shocks in stock prices. For what concerns the response of the macroeconomic variables to shocks in stock prices, they are negative over the short-run for GDP and consumer price index, but stabilize afterwards, and positive for money supply, exchange rate and interest rates. The response of interest rates is the most interesting, in our view, as they respond immediately in a positive manner to shocks in stock prices, but negatively for quarters five and six, and stabilize afterwards.

For Hungary we can observe an immediate negative response of stock prices to shocks in themselves, GDP, and money supply, but they are compensated over the long run. At the same time, the shock induced by GDP and money supply is more persistent in time, even until the eleventh quarter, but stock prices stabilize afterwards. The stock prices' responses to shocks in CPI, interest rates and exchange rates are positive in the first two to four quarters and they stabilize

immediately afterwards. After four quarters, the strongest reaction of stock prices is shown to innovations in themselves, but over the longer-run money supply shocks determine the strongest response of stock prices. For what concerns the shocks in macroeconomic variables induced by innovations in stock prices, they are showing an up and down pattern.

Figure 1. Impulse response functions – responses of stock prices to Cholesky one S.D. innovations



Czech Republic

Hungary

Poland

Romania

Poland shows a different situation in terms of stock prices' responses to shocks in macroeconomic variables. First, stock prices react negatively and dramatically to shocks in themselves in the first three quarters, then highly positively over the next two quarters, then negatively again for the next two quarters. Afterwards, positive and negative responses alternate, although their intensity is smaller. When all the other variables experience shocks, stock prices react positively to them over the first two to three quarters, then negatively over the next two to three quarters, and

stabilize over the longer run. Over a four quarters horizon, the strongest reaction of stock prices is to shocks in GDP and the lowest to shocks in interest rates, while after eight quarters the largest response is to shocks in stock prices and the smallest to shocks in CPI. Over the sixteen quarters horizon, stock prices react mostly to shocks in money supply and the least to shocks in CPI.

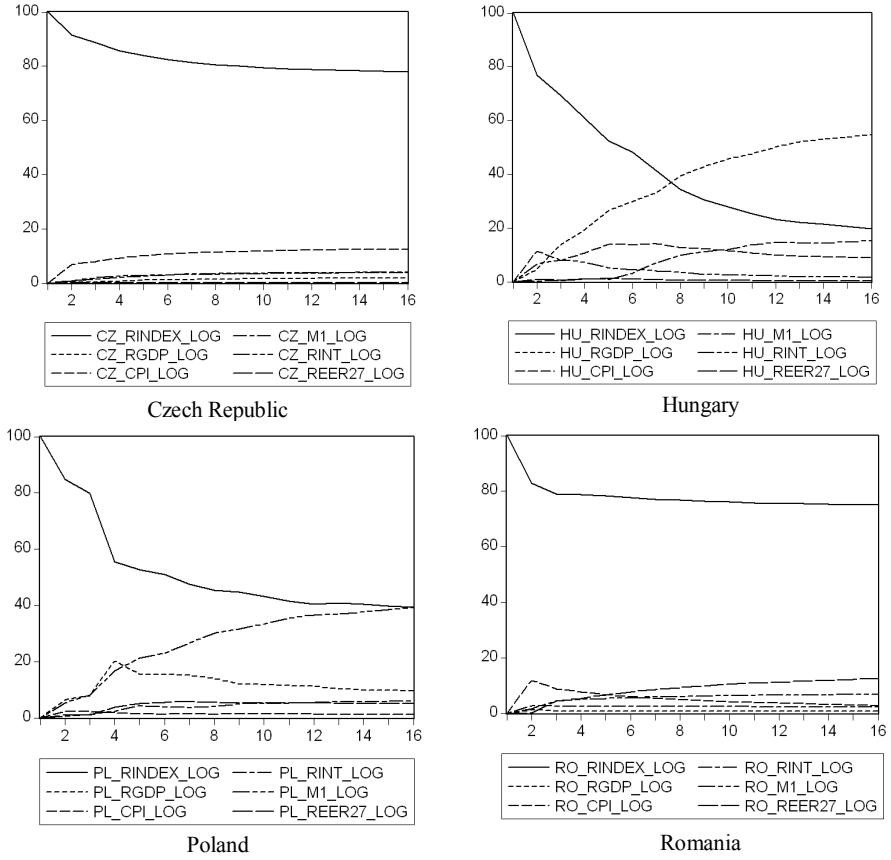
In the case of Romania, short-run negative responses of stock prices are to shocks in themselves, GDP, consumer price index and real exchange rate. These last for two to five quarters and diminish afterwards. The short-run positive responses of stock prices are found for interest rates and money supply and they are also declining over the long-run. Of all stock prices responses, those to shocks in themselves are the strongest over all forecast horizons, while the weakest responses are to innovations in consumer price index over the medium and longer run. The reaction of macroeconomic variables to shocks in stock prices, on the other hand, is diverse over the short run – positive for GDP, money supply and exchange rate and negative for consumer price index and interest rates – but over the long run shocks in these variables as result of shocks in stock prices diminish dramatically.

When we contrast the findings in terms of stock prices responses to one standard deviation shocks in the other macroeconomic variables between the four countries under analysis, we may observe only few similarities. The most obvious is that shocks in macroeconomic variables generate innovations in stock prices over the short-run, while over the longer-run (for some variables after eight lags and for all of them after sixteen quarters) stock prices stabilize and the effects of shocks in macroeconomic variables is not felt anymore. Another similarity refers to the same type of response of stock prices to shocks in themselves: for all countries this response is negative after the first quarters, and positive (with the notable exception of Romania) after four quarters. Also, money supply shocks are positive after four quarters for all countries, although they are either positive – for Poland and Romania – or negative – for Czech Republic and Hungary – after the first quarter. Shocks in GDP determine positive responses of all the four countries stock indices after four quarters, while after the first quarter the responses are negative for three of the countries (Czech Republic, Hungary and Romania) and positive for the fourth (Poland).

The decomposition of the forecast error variance of stock prices due to a shock in macroeconomic variables is reported in Figure 2. The variance decomposition analysis reinforced the results of impulse responses for all four countries under analysis. In the case of Czech Republic, the variance of stock prices holds the largest share in their own variance, over all forecast horizons – its contribution diminishes from 100% in the first quarter to 78% after four years. At the same time, the contribution of macroeconomic variables variance to short-term variance in stock prices is insignificant over the short-run and the long-run, with the exception of consumer price index variance, that is able to explain 12.5% of stock prices variance but only after four years. At its turn, stock prices variance does not explain to a large extent the variance of macroeconomic variables, with the notable

exception of interest rates: after the first quarter, stock prices variance explains 30% of interest rates variance but this share decreases to 21% after four years.

Figure 2. Variance decomposition of stock prices using Cholesky factorization



Hungary shows a different framework: in its case, although the short-term variance in stock prices is explained mainly by its own variance, it declines significantly over the long-term, representing only 20% after sixteen quarters. On the other hand, the explanatory power of the other macroeconomic variables variance for the stock prices variance increases from virtually null in the first quarter to 20% (GDP), 15% (money supply), and 9% (consumer price index) after four years. Stock prices variance impacts the variance of macroeconomic variables, but its contribution varies over the short-term as opposed to the long-term and among variables. Clearly, the highest contribution of stock prices variance is found in the case of consumer price index – its share reaches 46% after four quarters and remains at the same level even after sixteen quarters -, followed by the case of GDP, where the contribution of stock prices variance decreases from 15% over the short-run to 10% over the longer-run. An interesting situation is found in the case

of interest rates, where stock prices variance explains 40% of their variance after the first quarter, but this contribution declines to less than 9% after four years.
The same decline of stock prices' variance to its own variance is found in the case of Poland: the share diminishes from 100% after one quarter to 55% after four quarters to reach only 39% after four years. This decline in the share of stock prices variance is redistributed between the remaining of macroeconomic variables. Of them, money supply variance explains largely the variance in stock prices over the long run, followed by GDP variance. When we investigate the contribution of stock prices variance to the variance of macroeconomic variables, the highest over the short- and long-run is found for interest rates, while in the other variables case it is either important over the short-run and diminishing dramatically over the long-run or small for both horizons.
Romania's case is similar to the framework identified for the Czech Republic: here, the proportion of stock prices variance explained by their own variance is 100% for the first quarter and diminishes in time, but remains at an impressive 75% after four years. The real exchange rate variance increases in time, from virtually null in the first quarter to approximately 12% over a four-year horizon, while the contributions of the remaining macroeconomic variables variances to stock prices variance are small over both time horizons. On the other hand, stock prices variance is important over the short-run and the long-run for GDP, consumer price index and money supply.
In terms of variance decompositions, the striking resemblance between the four countries considered refers to the inability of macroeconomic variables variance to explain any proportion of the variance in stock prices in the short-run: after one quarter, stock prices variance explains 100% of its own variance in all four countries. At the same time, over the longer run, the contribution of stock prices variance to its own variance diminishes in all countries, but to a higher extent in Hungary and Poland. Another similarity comes from the real exchange rate variance, which, in all countries except Romania, is able to explain less than 5% of stock prices variance after four quarters and less than 10% after four years. Another interesting point to note is that Romania and Czech Republic seem to be more similar with regard to the variance of stock prices explained by variances in the other macroeconomic variables: in these countries no variable's variance is able to explain more than 15% of stock prices' variance for all time horizons.

5. Concluding remarks

Our paper addressed the long-term versus short-term dynamic relationships between stock prices and macroeconomic variables – gross domestic product, consumer price index, money supply, interest rates and exchange rates –, over the January 1998 – September 2007 period, using multivariate cointegration analysis accompanied by Granger causality tests and innovation accounting techniques. The analysis refers to a number of four countries from Central and Eastern Europe, specifically Czech Republic, Hungary, Poland and Romania.
The signs of variables in the cointegrating vectors are consistent with economic reasoning: the consumer price index is positively related to stock prices, while the

real exchange rate exhibits an opposite behaviour, except for the case of Romania. The relation between real GDP and stock prices is dependent upon economic cycles, which explains the separation observed between The Czech Republic and Hungary, on the one hand, and Romania and Poland, on the other. Real interest rates in The Czech Republic, Poland and Romania are, oddly, positively correlated with stock prices. Cautiously, we may interpret this behaviour as a lack of liquidity in financial markets over the period of study. In Hungary, Poland and Romania, the money supply is negatively correlated with the stock prices, indicating positive inflationary and portfolio substitution effects.

The results of the impulse response analysis point towards a number of similarities among the four countries. First, shocks in macroeconomic variables generate innovations in stock prices mainly over the short-run. Second, the responses of stock prices to shocks in themselves are negative over the first quarter and positive, except for Romania, after four quarters. Third, shocks in gross domestic product determine positive responses of stock prices in all four countries. In terms of variance decompositions, the striking resemblance between the four countries considered refers to the inability of macroeconomic variables variance to explain any proportion of the variance in stock prices over the short-run: after one quarter, stock prices variance explains 100% of its own variance in all four countries. Over the long run, the contribution of stock prices variance to its own variance diminishes in all countries, but to a higher extent in Hungary and Poland as compared to Czech Republic and Romania.

The current research represents a step in the direction of a better understanding of macroeconomic linkages in emerging countries from Central and Eastern Europe, nowadays part of the same process of harmonization and economic convergence as members of the European Union. A desired extension of this research refers to the use of cointegration, Granger causality tests and innovation accounting techniques with the aim of discovering patterns of convergence for countries from Central and Eastern Europe, among themselves and as components of the European Union.

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