The Relationship between Inflation, Output Growth, and Their Uncertainties: Evidence from Selected CEE Countries

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The relationship between inflation, output growth, and their uncertainties: Evidence from selected CEE countries[1]

ABSTRACT: *In this paper, we examine causal relationships among inflation rate, output growth rate, inflation uncertainty and output uncertainty for ten Central and Eastern European transition countries. For this purpose, we estimate a bivariate GARCH model that includes output growth and inflation rates for each country. Then we use conditional standard deviations of inflation and output to proxy nominal and real uncertainty, respectively, and perform Granger-causality tests. Our results suggest that inflation rate induces uncertainty about both inflation rate and output growth rate, which is detrimental for real economic activity. On the other hand, we find that output growth rate reduces macroeconomic uncertainty. In addition, we also examine and discuss causal relationships among remaining variables.*

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The relationship between inflation and economic growth is perhaps one of the most investigated yet controversial issues in macroeconomics on both the theoretical and empirical grounds. Macroeconomic models that incorporate nominal or real stickiness foresee a positive relationship between inflation and growth rates, at least in the short run. Such a positive relationship might arise even in absence of any stickiness and market imperfections, due to incorrect expectations about the future inflation rates (Friedman, 1968) or misperception of nominal shocks (Lucas, 1972). However, inflation is not costless. Higher rates of inflation may cause to reallocation of scarce resources to unproductive activities and thus distort economic efficiency and reduce output growth. In his Nobel Lecture, Friedman (1977) argued that inflation may have a negative effect on output growth by increasing inflation uncertainty. Ball (1992) formalized the ideas of Friedman (1977) and showed that inflation rate increases inflation uncertainty. Cukierman and Meltzer (1986), on the other hand, argued that the positive correlation between inflation and inflation uncertainty may stem from the positive effect of inflation uncertainty on average inflation rate. In addition to inflation uncertainty, it is generally agreed that real uncertainty may also affect output growth (Pindyck, 1991) and inflation rate (Devereux, 1989).

Although the relationships among inflation, output growth, inflation uncertainty and output uncertainty have been investigated extensively in the empirical literature for developed countries (e.g., Grier and Perry 1998; Davis and Kanago, 2000; Fountas et al. 2006; Fountas and Karanasos 2007)[2], a lesser work is done for economies in transition. Few exceptions are Gillman and Nakov (2004), Dibooglu and Kutan (2005), Gillman and Harris (2008), Mladenovic (2007), Thornton (2007), Erkam and Cavusoglu (2008), and Susjan and Redek (2008). Gillman and Nakov (2004) examined the relationship between inflation and output growth in Hungary and Poland, and found that inflation affects growth negatively in both countries. Gillman and Harris (2008) also found a robust negative effect of inflation on growth in a panel of 13 transition countries. Dibooglu and Kutan (2005) studied the sources of inflation and output movements in Poland and Hungary, and found that monetary shocks affect output in Hungary, while supply shocks dominate output movements in Poland. Mladenovic (2007) examined the relationship between inflation and inflation uncertainty in Serbia, and concluded that high inflation invokes high uncertainty, while high uncertainty negatively affects average level of inflation in the long run. Thornton (2007) studied the inflation and inflation uncertainty relationship for 12 emerging economies including Hungary, and found that there is positive bidirectional causality between inflation and inflation uncertainty in the case of Hungary. Erkam and Cavusoglu (2008) investigated the linkage between inflation and inflation uncertainty in seven former Soviet Union countries. They found that inflation rate increases uncertainty in three countries (Azerbaijan, Russia, and Ukraine) while uncertainty increases average inflation in Kyrgyzstan and Russia, but reduces it in Azerbaijan. Finally, Susjan and Redek (2008) provide strong evidence on negative effect of transition-specific uncertainties on economic growth for a panel of 22 transition countries.

The aim of this paper is to examine causality relationships among inflation, growth, and their uncertainties for ten Central and Eastern European (CEE) transition countries, namely for Bulgaria, Croatia, Czech Republic, FYR Macedonia, Hungary, Lithuania, Poland, Romania, Slovakia, and Slovenia, whose data were available on IMF's International Financial Statistics database. This particular choice is based on several factors. First, the CEE countries have experienced drastic movements in output and inflation rates during the transition period[2], which can be characterized by transitional uncertainty such as institutional transformation, political, social, and economic instability, and legacy of the past (Susjan and Redek, 2008). Therefore, the CEE countries provide a unique case for examination of the relationships between uncertainties and economic performance, and hence, such an examination may contribute to our understanding of relationships among inflation, growth and their uncertainties. Second, except for Croatia and FYR Macedonia, which are candidate countries, all of the countries considered are members of the European Union (EU) and in the process of entering to the Euro zone[3]. Since macroeconomic stability is one of the preconditions for entering the Euro zone, it is of particular interest to study the relationships among uncertainty, inflation and growth for the CEE countries. The casual relationships among these variables might sign clear policy implications for price and output stability. Third, besides macroeconomic stability, these countries also need to sustain relatively higher rates of growth in order to raise their per capita real income to the EU level. Therefore, the results of such a study might be guiding in macroeconomic policy design to attain desired growth rates for these countries.

In order to investigate the relationships among the said variables, we first estimate a bivariate generalized autoregressive conditional heteroscedasticity (GARCH) model that include output growth and inflation rates for each country. Then we use conditional standard deviations of inflation and output to proxy nominal and real uncertainty, respectively, and perform Granger-causality tests to examine the causal relationships among inflation, output growth, and their uncertainties.

The paper is organized as follows. In the next section we provide an overview of the literature on the relationships among inflation rate, output growth rate, and their uncertainties. In the third section we provide a brief overview of economic developments in the sample countries during the transition period. In the fourth section we outline econometric methodology. In the fifth section we provide and discuss results. The sixth and final section contains conclusions and implications of the study.

Overview of economic developments in the sample countries

One of the most challenging tasks for the transition countries was to implement massive structural reforms in order to restructure their centrally planned economies to a market economy, including price liberalization, trade liberalization, privatization and de-monopolization, and development of market institutions and legal framework for a market economy[4]. While most of the CEE countries (including Croatia, Czech Republic, Hungary, Lithuania, Poland, Slovakia, and Slovenia) launched liberalization reforms in early transition period, Bulgaria, FYR Macedonia and Romania lagged in implementing structural reforms (Fischer and Sahay, 2000; Gomulka, 2000). Since the CEE countries were industrialized and had well-educated work force, it was expected that removal of government control over economic activity and transformation to market economy will boost economies of these countries (Campos and Coricelli, 2002). The transitional contraction, however, was deeper than expected, and in most cases lasted longer than expected.

(Figure 1)

Table 1 presents summary data on macroeconomic performance of the sample CEE countries during the 1989-2007 period, and Figure 1 plots real GDP index of these countries. As can readily be seen from the figure, the sample CEE countries have experienced drastic output falls during the early stages of transition. By the time output reached its lowest level, it had fallen by 27% on average in these countries. Cumulative output fall during the transitional recession period varied considerably, from 13,1% in the Czech Republic to 46,7% in Lithuania. Explanations for such a severe recession include (i) disorganization or breakdown of the economic relations of the old regime, (ii) collapse of the arms industry and state-financed investment in housing, energy, agriculture and infrastructure, (iii) massive and rapid changes in relative prices, (iv) the huge amount of obsolete fixed capital in inefficient enterprises, (v) the low quality of domestically produced goods, and (vi) undeveloped financial system[5]. In addition to drastic falls in output, some countries suffered from hyperinflation as well. For instance, annual inflation rate was 1.935% in FYR Macedonia in 1992, 1.161% in Lithuania in 1992 and 1.149% in Croatia in 1993. Only the Czech Republic, Hungary and Slovak Republic managed to keep maximum annual inflation rate at two-digit levels throughout 1990s.

(Table 1)

Along with structural reforms, most transition countries have implemented stabilization programs in order to fight high and increasing inflation rates and prevent further output losses. The stabilization reforms in these countries were successful in reducing inflation rate and recovery from the recession[6]. In fact, as can readily be seen from the Table 1, output began to grow in the first half of 1990s in most sample CEE countries, and these countries enjoyed impressive output growth rates. Average output growth rate starting from the trough was 4,3%, with lowest rate of 2,7% in FYR Macedonia and highest rate of 6,3% in Lithuania. However, output loss during the early transition period was so much that only Poland and Slovenia surpassed their pre-transition output levels before the end of 1990s. Other countries, despite striking growth performance, exceeded their 1989 output levels only in 2000s.

After achieving macroeconomic stability, the economies of the sample CEE countries continued to grow at relatively higher rates as a result of rapid productivity gains due to economic restructuring. Intensified foreign direct investments as well as the start of EU-accession[7] process contributed to fast economic growth in the CEE transition countries. The reforms and efforts aimed at preparation for the EU membership created sound environment for economic activity and contributed to sustaining higher growth rates and keeping inflation rate at lower rates (e.g., Brada, 1998; Gomulka, 2000; Kutan and Yigit, 2007).

Literature Review

Although it has long been recognized that uncertainty might affect real variables, the relationship between uncertainty and economic variables was not examined until Okun (1971), who argued that "toleration of a higher inflation rate would mean less steady inflation". Okun (1971) examined the relationship between average rate of inflation and inflation variability in seventeen OECD countries for the period 1951-1968, and found a positive relationship between inflation rate and its variability. Gordon (1971), on the other hand, claimed that Okun's finding of high correlation between average rate of inflation and inflation variability is not universal and "is highly influenced by his choice of sample period". Friedman (1977) argued that higher rates of inflation induce higher uncertainty on future inflation due to erratic policy responses to increasing inflation rates. Friedman (1977) further maintained that an increase in inflation uncertainty distorts effectiveness of price mechanism in efficient resource allocation and thus increases unemployment. After Friedman's (1977) Nobel Lecture, the effects of uncertainty on macroeconomic variables have attracted a considerable interest of macroeconomists, and a huge amount of both theoretical and empirical work on the relationship between uncertainty and macroeconomic variables has been accumulated. In this section we provide a brief overview of the theoretical literature on the relationships among inflation, output growth and their uncertainties.

The Relationships among Macroeconomic Uncertainties and Inflation Rate

According to Okun (1971) and Friedman (1977), higher rates of inflation induce higher uncertainty about future inflation. Okun (1971) attribute observed positive relationship between average rate of inflation and inflation variability to "the ability and determination of public policy to apply corrective measures when the inflation rate exceeds acceptable limits." Friedman (1977), however, argues that such a positive relationship is a result of inconsistency of objectives of policy authorities. Primary objective of policymakers is to achieve full employment and price stability. In order to achieve full employment, governments launch expansionary monetary and fiscal policies, which actually generate higher inflation. But higher inflation rate produces strong political pressure to reduce it, leading to a switch to tighter monetary and fiscal policies. Such policy switches induce uncertainty about future policies, and thus widens variation in the actual and anticipated inflation. Ball (1992) formalizes arguments of Friedman (1977), and shows that if there is uncertainty about policymaker's tolerance of inflation, higher rates of inflation shall generate uncertainty about future monetary policy, and hence, higher inflation uncertainty. Similarly, Azariadis and Smith (1996) have shown that if there are informational frictions in the credit markets, higher rates of inflation lead to higher uncertainty. Pourgerami and Maskus (1987) and Ungar and Zilberfarb (1993), on the other hand, argue that agents may allocate more resources to inflation forecasting during higher inflationary periods, and thus inflation uncertainty may decline with increasing inflation rate.

Contrary to Friedman (1977) and Ball (1992), Cukierman and Meltzer (1986) suggest that the positive relationship between average inflation rate and inflation uncertainty may originate from the positive causal effect of inflation uncertainty on inflation rate. Cukierman and Meltzer (1986) show that if the public faces uncertainty about future monetary policy, and hence about future inflation, then "opportunistic" monetary authorities might implement expansionary policies to surprise the public, and thus enjoy output gains. Holland (1995), on the other hand, argues that if inflation uncertainty increases as a result of high inflation, then "stabilizing" monetary authorities might implement tighter policies to reduce inflation and inflation uncertainty and thus eliminate associated welfare costs.

In addition to inflation uncertainty, output uncertainty might also affect inflation rate. For example, Devereux (1989) shows that uncertainty about output growth reduces the degree of optimal wage indexation, and thus induces policy authorities to generate surprise inflation in order to obtain output gains. Cukierman and Gerlach (2003) show that even if policymakers target the normal level of employment, and if they are more sensitive to employment below than above normal level, then higher uncertainty about economic conditions shall generate inflation bias. Furthermore, if there is a positive relationship between output uncertainty and inflation variability as argued by Okun (1971), then output uncertainty shall be positively correlated with inflation according to Cukierman and Meltzer's (1986) hypothesis and negatively correlated according to Holland's (1995) hypothesis. On the other hand, if output and inflation uncertainties are negatively correlated as Taylor (1979) shows, then the sign of these correlations will be reversed.

The Relationships among Macroeconomic Uncertainties and Output Growth Rate

It has long been recognized that uncertainty might be detrimental for real economic activity. For example, Alfred Marshall has stated that uncertain future value of the English pound might have a negative effect on output (Jansen, 1989: p. 43). The effects of uncertainty on output growth rate, however, were first examined by Friedman (1977). Friedman (1977) argues that an increase in inflation uncertainty may raise the natural rate of unemployment in two rather different ways. First, inflation uncertainty shortens the optimum length of un-indexed commitments and renders indexing more advantageous. Since actual adjustment is time consuming, prior adjustments introduce rigidities that reduce the effectiveness of markets. Second, uncertainty about future path of price level renders market prices a less efficient system for coordinating economic activity. Friedman (1977) argues that the higher the variability of inflation, the harder it becomes to extract information about relative prices from absolute prices. Therefore, by reducing economic efficiency, greater inflation uncertainty reduces economic growth.

As argued by Chan (1994) and Huizinga (1993), inflation uncertainty might be incorporated into interest rates, and thereby affect the intertemporal allocation decisions. If there is a positive relationship between inflation uncertainty and interest rates (e.g. Cox et al., 1981; Chan, 1994), then uncertainty shall reduce output growth further by decreasing consumption and investment expenditures through interest rate channel. However, Juster and Wachtel (1972), Dotsey and Sarte (2000) and Jorda and Salyer (2003) argue that uncertainty increases precautionary savings and hence the pool of funds available to finance investment expenditures increases. Therefore, inflation uncertainty might positively affect output growth by reducing interest rates and stimulating investment.

Pindyck (1991), however, argues that both nominal and real uncertainty is detrimental for investment. According to Pindyck (1991), firms' irreversible investments are sensitive to uncertainty about future commodity prices as well as uncertainty about operating costs. Therefore, instead of investing, firms might be willing to postpone new investments and wait for arrival of new information that is likely to affect profitability of investments. Beaudry et al. (2001) argue that uncertainty reduces the cross-sectional dispersion of firms' investment rate and distorts their allocation of resources. Furthermore, if output variability is positively associated with the inflation variability as Okun (1971) argues, then output uncertainty will increase inflation uncertainty and thus reduce output growth as argued by Friedman (1977). Blackburn (1999), on the other hand, shows that if technology is endogenous, output stabilization policies will reduce the long-run growth of the economy. Blackburn and Pelloni (2004) argue that the relationship between output growth rate and output variability will be positive if real shocks dominate fluctuations in the economy, and negative if nominal shocks predominate. Blackburn and Pelloni (2005), however, argue that irrespective of the type of shocks, nominal rigidities and endogenous technology (learning-by-doing) give rise to a negative correlation between mean and variance of output growth. Galindev (2008), on the other hand, has shown that if productivity growth is predominantly driven by internal learning, the conclusions of Blackburn and Pelloni (2005) will be reversed.

The effects of output growth on macroeconomic uncertainty are also disputable in the literature. According to the Phillips curve, higher rates of output growth will raise inflation rate, and thus increase inflation uncertainty due to the Friedman-Ball hypothesis. Furthermore, an increase in inflation rate might induce uncertainty about future monetary policies as policy authorities might be willing to reduce inflation rate but reluctant to endanger output growth. Therefore, output growth and inflation uncertainty will be positively correlated. However, other theories suggest that output growth and inflation uncertainty are negatively correlated. First, if the aggregate supply curve moves rightwards due to favorable supply shocks and as a result inflation rate declines, then output growth and inflation uncertainty will be negatively correlated according to the Friedman-Ball hypothesis. Similarly, if output growth leads to less inflation due to inflation stabilizing policies, then output growth and inflation uncertainty will be negatively correlated. Second, Brunner (1993) argues that a decline in output growth might generate uncertainty about policy reactions, and thus might increase inflation uncertainty. Third, if agents allocate more resources to inflation forecasting as Pourgerami and Maskus (1987) and Ungar and Zilberfarb (1993) argue, then output growth will reduce inflation uncertainty. Finally, note that the effect of output growth on output uncertainty is also ambiguous. If output growth and inflation uncertainty are positively correlated, then output growth and output uncertainty shall also be positively correlated as Okun (1971) argues. However, if the Taylor's (1979) hypothesis (i.e., that inflation and output uncertainties are negatively correlated) holds, then output growth and output uncertainties shall be negatively correlated.

The Relationship between Inflation Rate and Output Growth Rate

The inflation-output relationship has usually been described using the Phillips curve, which assumes that inflation rate and output growth rate are positively correlated, at least in the short run. Such a positive relationship between inflation and output is a common feature of many macroeconomic models, including sticky-wage models (Fischer, 1977; Taylor, 1979; 1980), sticky-price (or menu costs) models (Parkin, 1986; Blanchard and Kiyotaki, 1987; Caplin and Spulber, 1987), as well as misperception model of Lucas (1972). In sticky-wage models, higher inflation rate reduces average real wages and thus increases employment and hence output. In menu costs models, inflation rate reduces relative prices of monopolistic firms and as a result, demand for their products and hence output rise in response to nominal demand shocks. According to Friedman (1968), if commodity prices respond to nominal shocks faster than prices of production factors, then inflation will reduce real wages and increase employment in the short run. However, in the long run, the economy shall return to natural unemployment rate. Lucas (1972) argued that if the information content of market prices is not sufficient to distinguish between real and nominal shocks, then producers shall increase their outputs in response to all price increases in the short run. Tobin (1965) and Mundell (1963) argued that inflation might permanently increase output growth rate by stimulating capital accumulation, because in response to inflation households would hold less in money balances and more in other assets. Fischer (1979), on the other hand, argued that although steady-state capital accumulation is independent of inflation rate, inflation might increase capital accumulation on the transition path to steady-state. However, as Temple (2000) argues, it would now be hard to find much support for the view that inflation can raise output in the long run. Indeed, real business cycle models (Long and Plosser, 1983; King and Plosser, 1984; Plosser, 1989) viewed fluctuations in real economic variables, including output, as results of variations in the real opportunities of the individual agents.

Another strand of the literature argued that inflation is detrimental for the output growth in the long run. Inflation might affect output growth rate negatively through different channels. First, as Friedman (1977) argues, higher inflation rates may cause to reallocation of scarce resources to unproductive activities and thus reduce output growth. Furthermore, inflation rate increases inflation uncertainty and distorts economic efficiency and thus reduces employment. Second, inflation may increase interest rates and thus reduce investment (Chan, 1994). Third, if cash is required to purchase capital goods, inflation may reduce steady-state capital stock (Stockman, 1981). Fourth, inflation may adversely affect bank lending and financial activity as Huybens and Smith (1999) argue, which, in turn, is positively correlated with real economic activity. Finally, inflation may increase user cost of capital and reduce investment (Feldstein, 1983).

The Relationship between Output and Inflation Uncertainties

The relationship between output growth variability and inflation rate variability was first examined by Okun (1971), who argued that output growth rate variability and inflation variability are positively correlated. According to Okun (1971), if the primary source of inflation variability stems from changes in the private demand moving along a given Phillips curve, then countries that tolerate wider swings in the inflation rate should also experience wider output fluctuations. On the other hand, if inflation variability is caused primarily by shifts in the Phillips curve, then countries that try to hold down and stabilize the inflation rate shall also experience a greater variability in output growth rate. Similarly, Logue and Sweeney (1981) argued that inflation uncertainty and output uncertainty might be positively correlated. Higher inflation uncertainty induces higher relative price variability, which, in turn, generates more variability in investment and output growth. In addition, output uncertainty might generate uncertainty about reactions of policy authorities, which eventually shall create uncertainty about future inflation rate. Furthermore, if inflation increases with output uncertainty as argued by Devereux (1989) and Cukierman and Gerlach (2003), output uncertainty and inflation uncertainty shall be positively correlated due to Friedman-Ball hypothesis. However, if inflation uncertainty declines with increasing inflation rates as Ungar and Zilberfarb (1993) argue, then inflation uncertainty and output uncertainty shall be negatively correlated.

Taylor (1979) using an econometric model consistent with a sticky prices and rational expectations, found a second order Phillips curve tradeoff between fluctuations in output and fluctuations in inflation rate. He argued that this tradeoff is downward sloping, and concluded that business cycle fluctuations could be reduced only by increasing inflation variability. Cecchetti and Ehrmann (1999) argued that aggregate shocks create a tradeoff between output and inflation variability. Similarly, Fuhrer (1997) showed that if monetary authorities target the level of inflation and the level of real output relative to potential, the existence of a tradeoff between the levels of inflation and output in the short-run would imply a long-run variance tradeoff. That is, in order to reduce inflation variability in the face of nominal and real shocks, the policy authorities must vary real output a great deal to stabilize inflation.

Econometric Methodology

As Evans (1991) argues, not every measure of variability of any variable can be considered as uncertainty about that variable. For example, if individuals have very little information, say, about the stance of the monetary policy, they will face a greater uncertainty about future inflation even though computed volatility of actual inflation rate is very small. However, if individuals are well informed about a major change in the stance of monetary policy, there will be a little uncertainty even in the case of large variation in inflation rate. Consequently, simple variance or another measure based on variability of observed economic variables may be misleading indicator of uncertainty. Furthermore, individuals form their expectations about the future on available information set. Therefore, expectations and volatility of economic variables must be defined conditionally on some information set. Recent empirical studies examining the effects of macroeconomic uncertainties tried to solve this problem by modeling relevant variables as autoregressive conditional heteroscedasticity (ARCH) or generalized ARCH (GARCH) processes. GARCH models have several advantages in estimating causal effects among macroeconomic uncertainty and economic activity[8]. First, GARCH models provide estimates of the variance of unpredictable innovations in variables that corresponds well to the notion of uncertainty. Second, GARCH methodology allows one to test whether the movement in the conditional variance of a variable over time is statistically significant. Finally, GARCH models allow simultaneous estimation of the conditional mean and conditional variance of variables, which is more efficient than a two-step approach. For these reasons, following Grier and Perry (2000), Fountas et al. (2006), and Fountas and Karanasos (2007), we use a bivariate GARCH models to estimate inflation and output uncertainties.

Let π_t and y_t denote the inflation rate and output growth rate, respectively. Then, a bivariate VAR model for inflation rate and output growth can be written as follows:

$$\mathbf{x_t} = \mathbf{\Phi}_0 + \sum_{i=1}^{p} \mathbf{\Phi}_i \mathbf{x_{t-i}} + \boldsymbol{\varepsilon}_t \qquad (3.1)$$

where $\mathbf{x}_t$ is a (2x1) column vector given by $\mathbf{x}_t = (\pi_t, y_t)'$, $\mathbf{\Phi_0}$ is (2x1) vector of constants, $\mathbf{\Phi}_i$, *i=1,2,…p* is the (2x2) matrix of parameters, and $\boldsymbol{\varepsilon}_t = (\varepsilon_{\pi t}, \varepsilon_{yt})'$ is a (2x1) vector of residuals, respectively. The optimal lag length p in (3.1) was selected using Akaike Information Criterion (AIC) with a maximum lag order of 12. We assume that the vector of residuals $\boldsymbol{\varepsilon}_t$ is conditionally normal with mean vector $\mathbf{0}$ and covariance matrix $\mathbf{H}_t$, that is,

$(\boldsymbol{\varepsilon}_t | \Omega_{t-1}) \sim \mathrm{N}(\mathbf{0}, \mathbf{H}_t)$ where Ω_{t-1} is the information set available at time t-1. We assume that the conditional covariance matrix $\mathbf{H}_t$ has the constant conditional correlation GARCH(1,1) structure proposed by Bollerslev (1990). In particular, we assume that:

$$h_{\pi t} = \alpha_\pi + \beta_\pi h_{\pi,t-1} + \gamma_\pi \varepsilon^2_{\pi,t-1},$$

$$h_{yt} = \alpha_y + \beta_y h_{y,t-1} + \gamma_y \varepsilon^2_{y,t-1}, \qquad (3.2)$$

$$h_{\pi yt} = \rho \sqrt{h_{\pi t}} \sqrt{h_{yt}}$$

where $h_{\pi t}$ and h_{yt} are the conditional variances of inflation rate and output growth rate, respectively, and $h_{\pi yt}$ is the conditional covariance between inflation residuals $\varepsilon_{\pi t}$ and output residuals ε_{yt}. It is assumed that α_i and $\gamma_i > 0$, $\alpha_i \geq 0$ for $i = \pi, y$ and $-1 \leq \rho \leq 1$ in (3.2).

The bivariate GARCH model given in (3.1) and (3.2) was estimated using the maximum likelihood estimation method with the BHHH numerical optimization algorithm proposed by Berndt et al (1974). Bollerslev (1990) has shown that the BHHH algorithm provides consistent estimate of the asymptotic covariance matrix of the coefficients for the constant conditional correlation model.

After estimating the bivariate GARCH model, we proxied inflation and output uncertainties by conditional variances, and then performed Granger causality tests to examine bidirectional causal relationships among inflation, output growth and their uncertainties. Alternatively, causal relationships among the considered variables can be tested using the simultaneous estimation strategy as in Grier and Perry (2000). For this purpose, one must estimate a bivariate GARCH-in-mean model where each conditional variance equation includes lagged values of both inflation and output growth rates. However, as Grier and Perry (1998) and Fountas et al (2006) argue, two-step strategy for testing causal effects has advantages over the simultaneous estimation approach. Specifically, the simultaneous estimation approach restricts the effects to occur within a month while the two-step Granger causality approach allows one to capture lagged causal effects. Furthermore, Grier and Perry (1998) show that inclusion of the lagged conditional means into the variance equations may violate non-negativity condition of the variances. Finally, Granger causality approach minimizes the number of parameters to be estimated.

Empirical results

In this paper, we use monthly data on consumer price index (CPI) and industrial production index (IP) as proxies for price index and output level. The data is taken from International Monetary Fund's International Financial Statistics database and cover 2000M1-2007M11 period for Bulgaria, 1996M3-2007M11 for Croatia, 1993M1-2007M11 for the Czech Republic, 1985M1-2007M11 for Hungary, 1997M1-2007M11 for Lithuania, 1993M1-2006M10 for FYR Macedonia, 1988M1-2007M11 for Poland, 1990M10-2007M11 for Romania, 1993M1-2007M11 for Slovakia, and 1991M12-2007M11 for Slovenia[9]. The inflation rate is measured as $\pi_t = (CPI_t - CPI_{t-1})/CPI_{t-1}$, and output growth rate is measured as $y_t = (IP_t - IP_{t-1})/IP_{t-1}$.

Our econometric methodology outlined in the previous section relies on the assumption that both the inflation rate and output growth rates are *I(0)* processes. Therefore, prior to estimation, we test for stationarity of the variables under investigation. For this purpose, we applied conventional ADF, PP, and KPSS stationarity tests, results of which are shown below in Table 2.

(Table 2)

The results of the unit root tests provided in Table 2 suggest that both the inflation rate and output growth rate are *I(0)* processes in all countries considered[10]. In the next step we estimate a bivariate VAR model for inflation and output growth rates. The lag order in the VAR model was selected using AIC with maximum lag order of 12. In the literature, different specifications were proposed for the conditional covariance matrix. In addition to constant conditional correlation (CCC-GARCH) model of Bollerslev (1990), we also estimated conventional simple GARCH(1,1), dynamic correlation (DC-GARCH), BEKK, as well as exponential-GARCH (EGARCH) specifications for the conditional variance models. As shown in Table 3, the AIC criterion selects constant conditional correlation model as the most appropriate model in all cases. Therefore, we imposed constant conditional correlation GARCH(1,1) structure as given in (3.2) on the covariance matrix $\mathbf{H}_t$. The estimates are provided below in Table 4.

(Table 3 and Table 4)

After estimating GARCH models, we carry out residual diagnostic tests to test whether the estimated models capture joint distribution of the residuals reasonably well. Specifically, we calculate Ljung-Box Q statistics for the level, square, and cross-equation products of the standardized residuals. The results are provided in Table 5, and suggest that the estimated models are satisfactory.

(Table 5)

Following earlier practice in the literature (e.g, Grier and Perry, 1998; Fountas et al, 2006; Fountas and Karanasos, 2007; Thornton, 2007), we carried out Granger-causality tests using four, eight and 12 lags[11]. Tables 6, 7, and 8 below report *F*-statistics of bivariate Granger-causality tests for the relationship among inflation rate, output growth rate, inflation uncertainty and output uncertainty as well as signs of the sums of lagged coefficients if *F*-statistics are statistically significant.

Casual Relationship among Inflation Rate, Inflation Uncertainty, and Output Uncertainty

We first consider casual relationships among inflation rate and macroeconomic uncertainties. Table 6 provides the results of Granger-causality tests for the relationship among inflation, inflation uncertainty and output uncertainty. Panel A of the Table 6 reports the results of the tests of the null hypothesis that inflation rate does not Granger-cause inflation uncertainty. As the results suggest, the Friedman-Ball hypothesis finds support for Bulgaria, Croatia, Czech Republic, Hungary, FYR Macedonia, Poland, Romania, and Slovakia. The evidence is stronger for Croatia, Czech Republic, Hungary, FYR Macedonia, Poland and Romania, for which the null hypothesis is rejected for all lags considered.

(Table 6)

Panel B of the table shows the results of the tests for casual effects running from inflation uncertainty to inflation rate. The Cukierman-Meltzer (1986) hypothesis that inflation uncertainty raises inflation rate is supported only for Hungary and FYR Macedonia, implying that policy authorities of these countries might be “opportunistic” in the sense that they might be willing to generate surprise inflation to obtain output gains. On the other hand, the

Holland's (1995) hypothesis that inflation uncertainty reduces average inflation rate is supported in the cases of Bulgaria, Croatia, Czech Republic, Poland, Romania and Slovakia, suggesting that the policy authorities of these countries might be "stabilizing". Grier and Perry (1998) argued that "opportunistic" or "stabilizing" policy responses to increased uncertainty might depend on the degree of central bank independence. Recently, Cukierman et al. (2002) developed indices for legal central bank independence and examined the relationship for between central bank independence and inflation rate. In general, our results comply with arguments of Grier and Perry (1998) except for Hungary, central bank of which was rated as relatively independent by Cukierman et al. (2002). Note that Thornton (2007) also found that inflation uncertainty increases inflation rate in Hungary. This result may be due to the fact that starting from March 1995 Hungary has implemented a crawling band exchange rate system aimed at stabilizing nominal exchange rate and preventing significant real appreciation of national currency (Dibooglu and Kutan, 2005). As Obstfeld and Rogoff (1995) argue, central banks that target nominal exchange rates lose control over domestic money supply, and hence over inflation rate. Since Hungary has enjoyed huge capital inflows during the post-1995 period, this result is not surprising.

In Panel C of the table we report the results of Granger-causality tests from inflation to output uncertainty. The results suggest that inflation rate increases output uncertainty only in four countries, namely, Bulgaria, Croatia, Hungary and Lithuania. Such a positive effect of inflation on output variability can be explained by the Friedman-Ball hypothesis and Okun's (1971) proposition. According to Friedman-Ball hypothesis, inflation rate increases inflation uncertainty, which is positively correlated with output uncertainty as Okun (1971) argues. For example, in the case of Hungary, we found that inflation rate increases inflation uncertainty, which, in turn, has a positive effect on output variability (see Panel D of Table 8).

Now consider the effects of output uncertainty on inflation rate. The results of tests for the effects of output uncertainty on inflation rate are provided in Panel D of the table. The results suggest that output uncertainty increases inflation rate in FYR Macedonia and Poland, and reduces it in Bulgaria. A positive effect of output variability on inflation rate might stem from stabilizing policies or opportunistic behavior of central banks as Devereux (1989) argues. Indeed, as Dibooglu and Kutan (2005) argue, primary objective of policies in Poland was stimulating growth. The negative effect in the case of Bulgaria may be justified by the interactions between output uncertainty, inflation uncertainty and inflation rate. We find that output uncertainty increases inflation uncertainty (see Panel C of Table 8 below) and inflation uncertainty reduces inflation rate in Bulgaria possibly as a result of inflation stabilizing policies.

Casual Relationship among Output Growth Rate, Inflation Uncertainty, and Output Uncertainty

Next we consider the causal relationships among output growth rate, inflation uncertainty, and output uncertainty. The results of Granger-causality tests among these variables are provided below in Table 7. In panel A of Table 7 we report results of the causality tests running from inflation uncertainty to output growth. The results suggest that inflation uncertainty reduces output growth in Croatia, Hungary, Poland, and Romania, which complies with Friedman's (1977) arguments. On the other hand, the results suggest that inflation increases output in Bulgaria, although evidence is weak. As Dotsey and Sarte (2000) and Jorda and Salyer (2003) argue, inflation uncertainty may increase precautionary savings and thus reduce interest rates. Therefore, the effects of inflation uncertainty on output may be positive if indirect effects of uncertainty through interest rate channel outweigh direct negative effects.

(Table 7)

Now consider the effects of output uncertainty on output growth rate. The results of the causality tests are provided in Panel B of Table 7. The test results imply that output uncertainty reduces growth rate in Croatia, Hungary and Poland, and increases it in the cases of Bulgaria, Lithuania and FYR Macedonia. The results for Croatia, Hungary and Poland support the views of Pindyck (1991) and Beaudry et al. (2001), who argued that uncertainty is detrimental for investment. Since investment is one of the components of GDP, it is natural that a reduction in investment will eventually reduce GDP. In addition, and perhaps most importantly, investment level determines future capital stock, and thus affects future output level directly. These results also support the arguments of Blackburn and Pelloni (2005), who have shown that nominal rigidities and endogenous technology (learning-by-doing) give rise to a negative correlation between output growth rate and output variability. Blackburn (1999) and Blackburn and Galindev (2003), on the other hand, argued that reducing output variability might reduce long-run economic growth. Galindev (2008) also has shown that if productivity growth is predominantly driven by internal learning rather than external learning, then output variability and output growth rate will be positively correlated. Thus, the results for Bulgaria, Lithuania and FYR Macedonia suggest that internal learning might be predominant for productivity growth in these countries.

Panel C of Table 7 reports the effects of output on output uncertainty. The Granger-causality tests imply that higher output growth rate reduces output variability in Bulgaria, the Czech Republic, Hungary, Lithuania, Poland, Romania and Slovenia, and increases it in the cases of Croatia FYR Macedonia. Direct causality running from output growth rate to its uncertainty is not examined in the theoretical literature (see also Fountas et al. 2006). A possible explanation may be traced in the interactions among output growth, inflation, and inflation uncertainties. For example, in the case of Croatia we find that output growth rate reduces inflation (see Panel B of Table 8 below) which, in turn, reduces inflation uncertainty. A decline in inflation uncertainty eventually reduces output uncertainty (see Panel D of Table 8) in line with Okun's (1971) arguments. In the cases of Bulgaria, the Czech Republic, Hungary, Lithuania, Poland, Romania and Slovenia, for which we find that output growth rate reduces its uncertainty, other mechanisms must be at work to explain such a negative effect. Note that these countries have undergone major institutional transformation during the transition period, which enhanced uncertainty surrounding their economic environment (Susjan and Redek, 2008). However, transformation to free market economy increased productivity of these countries, and as a result, starting from mid-1990s these countries enjoyed relatively higher growth rate (see, e.g., Gomulka, 2000; Campos and Coricelli, 2002; Fischer and Sahay, 2000; Dibooglu and Kutan, 2005). Rapid productivity gains due to economic restructuring and integration to the EU, which was engine of output growth, might also have reduced uncertainty about output growth in these countries.

Panel D of Table 7 provides results of the causal effects of output growth on inflation uncertainty. The results suggest that output growth reduces inflation uncertainty in Hungary, Poland, and Slovenia, whereas in other countries the casual effect is statistically indifferent from zero. The results for Hungary and Poland may be explained by the relationship between output growth rate, output uncertainty and inflation uncertainty. In these two countries output reduces output uncertainty, which in turn, positively affects inflation uncertainty (see Panel C of Table 8). For Slovenia, on the other hand, we find that output uncertainty reduces inflation uncertainty. Therefore, other indirect effects should be stronger in order to give a rise to a negative effect of output on inflation uncertainty. For example, exchange rate targeting may account for such a negative effect. If central banks target (explicitly or implicitly) nominal exchange rates, then exchange rates shall be less volatile. Furthermore, if a country enjoys huge foreign direct investments as in the case of Slovenia (Bohnec, 2003), then output growth enhanced by capital inflows may have a negative effect on inflation variability due to a reduced volatility in exchange rates. Indeed, Frömmel and Schobert (2006) find that Slovenia implicitly targeted nominal exchange rate.

Casual Relationship among Inflation Rate, Output Growth Rate, and Their Uncertainties

Finally, we consider the causal relationships between inflation and output growth rates as well as between inflation and output uncertainty. In Panel A of Table 8 we report the results of the tests for causal effects of inflation on output growth rate. The results suggest that higher inflation rate reduces output growth rate in Croatia, FYR Macedonia, Poland, Romania and Slovenia, providing support for the arguments Stockman (1981), Feldstein (1983), and Huybens and Smith (1999). In the case of Lithuania, however, inflation increases output growth. This result accords with a wide variety of macroeconomic models, including textbook aggregate supply and aggregate demand models as well as market imperfection models.

(Table 8)

Panel B of Table 8 reports the results of causality tests running from output growth to inflation rate. The results indicate that higher output growth rate increases inflation rate in the Czech Republic, Lithuania, FYR Macedonia and Romania, and reduces it in Croatia and Poland. The effect of output growth rate on inflation rate is disputable in the literature. If output growth rate increases due to productivity gains, which is the case for transition countries, and as a result aggregate supply curve moves rightwards, then output growth rate will reduce inflation rate. On the other hand, the standard Phillips curve relationship suggests that inflation and output are positively correlated. The findings for the Czech Republic, Lithuania, FYR Macedonia and Romania suggest that the Phillips curve effect outweigh negative effects of a shift in the aggregate supply curve.

Finally, we test for the causal relationships between inflation and output uncertainties. As discussed earlier, the theory suggests that these two uncertainties may be both positively and negatively correlated. Panel C of Table 8 provides the results of tests for the effects of output uncertainty on inflation uncertainty. The results imply that output uncertainty increases inflation uncertainty in Bulgaria, Hungary, Poland and Romania in accordance with arguments of Okun (1971) and Logue and Sweeney (1981). Such a result may be due to the fact that output variability induces uncertainty about reaction of policy authorities, which eventually generates uncertainty about future inflation rates. In the cases of Croatia, Lithuania, and Slovenia, however, we find that output uncertainty affects inflation uncertainty negatively. This finding is in line with arguments of Taylor (1979), who stated that business cycle fluctuations can be reduced only by increasing inflation variability.

In Panel D we provide the results for the causal effects of inflation uncertainty on output uncertainty. Our results suggest that higher inflation uncertainty increases output uncertainty in Croatia, Hungary and Romania, and reduces it in Bulgaria. The results for Croatia, Hungary and Romania comply with arguments of Logue and Sweeney (1981). They argued that higher inflation uncertainty induces higher relative price variability, which, in turn, generates more variability in investment and output growth. The results for Bulgaria may be due to inflation stabilization efforts. During early transition period, Bulgaria suffered from both higher inflation rate and excess inflation variability when compared to other CEE transition countries (Hristov and Zaimov, 2003). In 1997, Bulgaria adopted currency board regime, and as a result, both mean and variability of inflation rate decreased significantly thereafter. Fuhrer (1997) argued that the policy authorities must vary real output a great deal to stabilize inflation, which suggests that inflation variability has a negative effect on output variability.

Conclusion

The theoretical literature on the interrelationship among inflation rate, output growth rate and macroeconomic uncertainties is ambiguous. Therefore, total effect of one variable on another depends on relative importance of direct and indirect causal effects as well as macroeconomic environment and economic policies to a great extent. Although the causal relationships among macroeconomic and various uncertainties have been examined in the empirical literature extensively for developed countries, only a limited work is done for transition economies. Considering both the theoretical and practical importance of causal relationships among these variables, and with the aim to fill a gap in the literature, in this paper we examine such relationships for ten Central and Eastern European transition countries. Our findings can be summarized as follows.

First, we find overwhelming evidence in favor of the Friedman-Ball hypothesis. Particularly, the Granger-causality tests suggest that inflation rate increases uncertainty about inflation in eight out of total 10 countries, and in two remaining countries, the effect of inflation rate on inflation uncertainty is statistically indifferent from zero. Similarly, we find that inflation rate increases output uncertainty in three countries, while in the remaining countries the effect of inflation on output uncertainty is not statistically significant. These results suggest that, on average, inflation rate increases macroeconomic uncertainty in CEE transition countries.

Second, our results suggest that output growth reduces output uncertainty in seven countries, and increases it only in one country. Furthermore, output growth rate reduces uncertainty about future inflation in three countries, while has no (statistically significant) effect in other countries. This finding indicates that higher output growth rates reduce macroeconomic uncertainty for these countries on average.

Third, the results indicate that inflation uncertainty reduces inflation uncertainty in six countries. This finding implies that most CEE countries might have been implementing inflation stabilizing policies in the sense that the monetary authorities choose to implement tighter policies to reduce inflation and inflation variability in the face increasing inflation variability as argued by Holland (1995). On the other hand, we find that inflation rate increases with inflation uncertainty only in two countries, in accordance with Cukierman and Meltzer's (1986) hypothesis. As regards the effects of inflation uncertainty on real economic activity, we find that uncertainty about inflation rate reduces output growth rate in four countries, and increases it only in one country.

Fourth, the results provide mixed evidence for the effects of output uncertainty on output growth rate and inflation rate. Specifically, the effects of output uncertainty has no statistically significant effect in seven countries whereas it increases inflation rate in two countries, namely, in FYR Macedonia and Poland, possibly due to output stabilization policies, and reduces it in only one country, Bulgaria. Our results further imply that output uncertainty increases output in two countries (Bulgaria and Lithuania), and reduces it in three countries (Croatia, Hungary, and Poland).

Some of these findings can be attributed to transition-specific features as well as macroeconomic policies implemented in these countries. However, further work must be carried out to examine direct and indirect interrelationships among these variables as well as the association of these causal effects with country-specific features and macroeconomic policies. For example, considering the fact that other macroeconomic variables such as interest rate and foreign exchange rate play crucial role on the determination of both price and output levels, empirical studies on the effects of uncertainty on interest rate and exchange rates might shed light on indirect causal effects among macroeconomic variables and their uncertainties. Furthermore, one of the avenues for further research might be examination of possible structural breaks and nonlinearities in the interrelationship between these variables.

All in all, our results imply that higher inflation rate increases macroeconomic uncertainty, both real and nominal, which is detrimental for real economic activity. On the other hand, we found that higher output growth rate reduces uncertainty about macroeconomic environment. This result may be due to the fact that radical structural changes and institutional reforms resulted in rapid productivity gains, which might have reduced transition-specific uncertainties augmented with macroeconomic uncertainty to a great extent. Our results suggest that one of the primary objectives of policy authorities must be to achieve economic stability in order to stimulate output growth further.

Notes

1. Preliminary version of the paper was presented at international conference "Economies of Central and Eastern Europe: Convergence, Opportunities and Challenges" held from 14th to 16th June 2009 in Tallinn, Estonia. We would like to thank the participants of the conference, Professor Alovsat Muslumov, two anonymous referees, and editor of this journal for their helpful comments and suggestions on the earlier version of the paper. All remaining errors and shortcomings are the responsibility of the authors.

2. Temple (2000) provides a comprehensive literature survey on output effects of inflation and inflation uncertainty.

3. Of the sample countries, only Slovenia and Slovakia joined the Euro zone in 2007 and 2009, respectively.

4. Blanchard (1997), Gomulka (2000) and Roland (2000) provide overview of reforms in transition countries.

5. For a thorough analysis of economic developments in transition countries see, for example, Kornai (1994), Gomulka (2000), Wyplosz (2000), Campos and Coricelli (2002).

6. Fisher et al. (1996), Wyplosz (2000) and Fischer and Sahay (2000) examine stabilization efforts of transition countries as well as the relationship between stabilization and growth in these countries. They find that stabilization programs have helped to reduce inflation rate and foster output recovery during the early transition period. For a thorough discussion of macroeconomic policies implemented in the transition countries throughout 1990s see Gomulka (2000).

7. Accession negotiations with Bulgaria, Czech Republic, Hungary, Lithuania, Poland, Romania, Slovakia and Slovenia in December 1997, and in January 2007 with Croatia and FYR Macedonia. Czech Republic, Hungary, Lithuania, Poland, Slovakia and Slovenia joined the EU in 2004 whereas Bulgaria and Romania in 2007.

8. For a thorough discussion of this issue see Grier and Perry (2000) and Fountas et al. (2006).

9. The sample period was dictated by data availability. All data were seasonally adjusted using the Tramo/Seats methodology.

10. In addition, we also estimated the fractional differencing parameter and autocorrelation functions for the series under investigation. The results imply that all the series can be regarded as stationarity. The estimates of the fractional differencing parameters and associated standard errors are available upon request.

11. In order to test for causal relationships among variables of interest, one may first select "optimal" lag length and then perform Granger-causality tests. However, different model (or lag) selection criteria may also point to different lag structures, which questions "optimality" of the selected lag order. Therefore, and in order to see whether the results of the causality tests change with model specification or not, following previous empirical studies in the literature we carried out the Granger-causality tests for three different lag structures. Naturally, different model specifications may give conflicting results (see, for example, Thornton, 2007; Fountas and Karanasos, 2007). In cases when different lag structures give conflicting results, one may resort to model selection criteria to choose appropriate lag structure and see the direction of causality. In this paper we indicate optimal lag length selected by the AIC in boldface. Throughout the remaining parts of the paper, if different lag specifications provide conflicting results regarding the direction of the causal relationship, we mention only the sign of the relationship suggested by the optimal model according to the AIC.

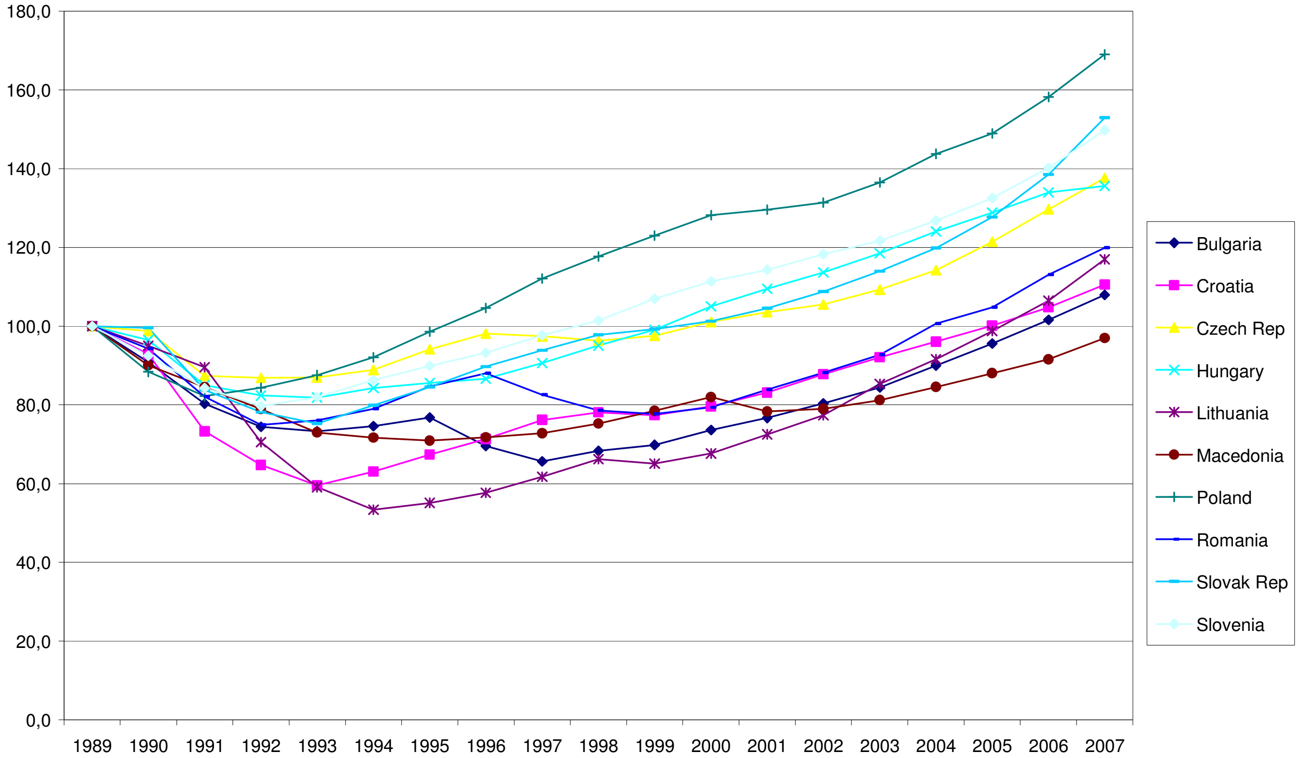

Figure 1. Real GDP index of the sample CEE Countries

Table 1. Macroeconomic Performance in the sample CEE Countries, 1989-2007

Country	Cumulative output decline to the lowest level (1989=100)	Year in which output was lowest	Cumulative output growth since lowest level	Year in which output surpassed its 1989 level	Maximum annual CPI-based inflation	Year in which inflation was highest
Bulgaria	34,3	1997	64,3	2006	578,6%	1997
Croatia	40,5	1993	85,7	2005	1.149,3%	1993
Czech Republic	13,1	1992	58,4	2000	56,6%	1991
Hungary	18,1	1993	65,6	2000	33,4%	1990
Lithuania	46,7	1994	119,3	2006	1.161,1%	1992
FYR Macedonia	29,1	1995	36,7	-	1.935,0%	1992
Poland	17,8	1991	105,5	1996	639,6%	1989
Romania	25,1	1992	60,0	2004	295,5%	1993
Slovak Republic	24,7	1993	103,3	2000	58,3%	1991
Slovenia	20,3	1992	88,0	1998	240,6%	1991

Source: EBRD, Selected economic indicators. Available online at: http://www.ebrd.com/country/sector/econo/stats/sei.xls.
Notes: Inflation data were available since 1989 for Bulgaria, Hungary, Romania, since 1990 for the Czech Republic and Slovak Republic, since 1991 for Croatia and Slovenia, and since 1992 for FYR Macedonia and Lithuania. The output level in FYR exceeded its 1989 level only in 2008.

Table 2. Stationarity Test Results

Country	Output Growth Rate			Inflation Rate		
	ADF	**PP**	**KPPS**	**ADF**	**PP**	**KPPS**
Bulgaria	-9.385*(0)	-9.388*	0.132	-6.769*(0)	-6.761*	0.095
Croatia	-9.855*(3)	-54.695*	0.145	-10.003*(0)	-10.043*	0.076
Czech Republic	-19.169*(0)	-20.625*	0.132	-2.583***(5)	-10.646*	0.194
Hungary	-9.070*(2)	-23.518*	0.093	-1.166(11)	-12.160*	0.040
Lithuania	-9.207*(3)	-31.615*	0.249	-8.787*(0)	-8.904*	0.310
FYR Macedonia	-11.438*(2)	-22.309*	0.206	-10.596*(0)	-10.680*	0.311
Poland	-7.954*(2)	-23.617*	0.100	-4.105*(5)	-7.432*	0.131
Romania	-19.380*(0)	-19.423*	0.074	-4.810*(1)	-7.092*	0.290
Slovakia	-15.439*(0)	-24.309*	0.101	-10.754*(0)	-10.721*	0.198
Slovenia	-18.090*(0)	-21.056*	0.096	-9.484*(1)	-9.601*	0.102

Notes: Augmentation terms used in the unit root regressions are provided in parenthesis. *, **, and *** denote rejection of the null hypothesis of unit root at 1%, 5%, and 10% significance levels, respectively. KPSS test differs from the ADF adn PP tests in that the former assumes that the series under investigation are stationary under the null hypothesis. Critical values of the KPSS test at %, 5%, and 10% significance levels are 0.739, 0.463, and 0.347, respectively.

Table 3. Estimates of bivariate GARCH models

	Countries									
	BG	HR	CZ	HU	LT	MC	PL	RO	SK	SI
Panel A. Estimates of the mean output equation										
Constant	0.007***	0.010***	0.008*	0.009*	0.009	-0.002	0.012***	0.010*	0.008***	0.002
y_{t-1}	-0.014*	-0.501*	-0.464*	-0.466*	-0.337*	-0.443***	-0.546***	-0.314***	-0.624***	-0.337*
y_{t-2}		-0.610*	-0.207*	0.017	-0.166**	-0.597***	-0.197***	-0.284***	-0.290***	-0.197*
y_{t-3}		-0.509*	-0.015*	0.158***		-0.511***	0.116*	-0.190*		-0.180*
y_{t-4}		-0.455*	-0.029			-0.384***	-0.128*			-0.121
y_{t-5}		-0.216*	0.099			-0.229***	-0.043			-0.078
y_{t-6}		-0.137	0.009			-0.013	0.112*			-0.038
y_{t-7}										-0.273
π_{t-1}	0.109*	0.095*	0.0004	-0.143	-0.421	0.081	-0.202***	0.119	0.046	0.086
π_{t-2}		0.005	0.036*	0.010	1.636	0.704	0.061	-0.115	-0.034***	0.040
π_{t-3}		-0.006	0.006	-0.126		-0.730**	-0.0412	-0.276*		-0.223
π_{t-4}		-0.009	0.025			-0.171	0.0112			0.228
π_{t-5}		-0.003	0.016			-0.074	-0.236***			-0.120
π_{t-6}		-0.079***	0.054*			-0.185	0.095			0.135***
π_{t-7}										0.526***
Panel B. Estimates of the mean inflation equation										
Constant	0.004***	-0.002***	-0.472**	0.089***	0.001***	0.001	0.0002	0.236***	0.004***	0.002***
y_{t-1}	-0.134**	0.005	0.011	-0.058	0.008	0.017*	0.026	0.648	-0.004	-0.010
y_{t-2}		0.025**	-0.277	-0.048	-0.003	0.010	0.026	0.023**	0.002	0.005
y_{t-3}		0.025**	0.219	-0.050		0.002	0.028	-0.379		-0.002
y_{t-4}		0.013	-0.833*			-0.009	0.027			-0.004
y_{t-5}		0.037***	-0.421*			0.008	0.828			-0.012
y_{t-6}		0.035***	0.018			0.001	-0.691			0.013
y_{t-7}										0.345***
π_{t-1}	0.430***	0.121***	0.042*	0.312***	0.232**	0.514***	0.553***	0.380***	0.354***	0.102
π_{t-2}		-0.020	0.174*	0.049	0.070	0.094	-0.168***	0.142**	-0.107	0.078
π_{t-3}		0.190*	0.020	0.036		-0.004	0.176***	0.224***		0.113
π_{t-4}		0.463***	0.056			0.049	0.230***			-0.156**
π_{t-5}		0.010	-0.021			0.155***	-0.053			0.135*
π_{t-6}		0.127***	0.047*			-0.161***	-0.020			-0.004
π_{t-7}										0.036
Panel C. Estimates of the variance equation of output growth rate										
α_y	$6x10^{-6}$	0.0004	0.0001*	0.000	0.003	0.015***	0.848	0.135***	0.0004	0.0001***
β_y	0.924***	0.859***	0.053	0.870***	0.398	0.744***	0.967***	0.465	0.158***	0.705***
γ_y	0.056	0.009***	0.702*	0.129***	0.136	0.130***	0.011	0.193**	0.027	0.012***
ρ	$7x10^{-5}$***	$2x10^{-5}$***	6.42e-06*	0.000	$2x10^{-7}$	$8x10^{-5}$***	0.007	0.004	$3x10^{-5}$***	$1x10^{-6}$
Panel C. Estimates of the variance equation of inflation rate										
α_π	0.350***	0.099***	0.123*	0.411***	0.005***	0.029	0.901***	0.057	0.005***	0.148*
β_π	0.010***	0.161***	0.023	0.945***	0.465***	0.008	0.779***	0.763***	0.465***	0.916***
γ_π	0.422*	0.828***	0.679*	0.054***	0.193***	0.698***	0.220***	0.295***	0.193***	0.038

Notes: BG = Bulgaria, HR = Croatia, CZ = Czech Republic, HU = Hungary, LT = Lithuania, MC = FYR Macedonia, PL = Poland, RO = Romania, SK = Slovakia, SI = Slovenia
*,**,*** denote significance at 1%, 5%, and 10% significance levels, respectively.

Table 4. Akaike Information Criterion for various Model Specifications

	Countries									
	BG	HR	CZ	HU	LT	MC	PL	RO	SK	SI
Simple GARCH(1,1)	-1432	-1482	-1482	-2961	-1829	-1895	-2745	-2358	-2838	-2838
CCC- GARCH(1,1)	-1448	-1498	-1498	-2977	-1845	-1911	-2761	-2374	-2854	-2854
DC-GARCH(1,1)	-1336	-1386	-1386	-2865	-1733	-1799	-2649	-2262	-2742	-2742
BEKK	-1440	-1490	-1490	-2969	-1837	-1903	-2753	-2366	-2846	-2846
EGARCH	-1347	-1458	-1458	-2929	-1816	-1802	-2716	-2271	-2483	-2483

Notes: BG = Bulgaria, HR = Croatia, CZ = Czech Republic, HU = Hungary, LT = Lithuania, MC = FYR Macedonia, PL = Poland, RO = Romania, SK = Slovakia, SI = Slovenia

Table 5. Residual diagnostic tests

	Countries									
	BG	HR	CZ	HU	LT	MC	PL	RO	SK	SI
Inflation Equation										
Q_4	5.24	6.04	6.31	6.34	5.04	7.90	8.26	8.38	3.24	5.35
Q_{12}	17.70	16.21	14.56	16.71	16.38	18.76	20.70	20.96	13.24	17.06
Q_4^2	1.58	1.98	2.84	2.20	1.39	2.52	4.06	4.21	1.03	1.35
Q_{12}^2	5.45	4.23	2.65	4.95	4.76	6.59	8.90	9.05	3.46	5.03
Growth Equation										
Q_4	3.07	2.47	2.65	3.02	2.78	4.07	6.28	5.37	4.31	4.04
Q_{12}	17.50	15.33	14.93	17.20	16.98	18.56	19.47	18.50	14.43	18.49
Q_4^2	2.25	1.38	1.54	2.16	2.19	2.85	3.92	3.29	1.26	3.27
Q_{12}^2	7.21	6.24	5.21	7.16	7.09	7.91	9.68	8.95	5.65	8.24
Growth Equation										
Q_4	2.22	2.38	3.56	2.25	2.01	3.28	5.03	4.26	1.65	2.62
Q_{12}	5.53	5.65	6.75	5.65	5.19	6..35	9..56	8.64	3.65	5.35

Notes:
Q_4 is the fourth order Ljung-Box test for standardized residuals.
Q_{12} is the 12th order Ljung-Box test for standardized residuals.
Q_4^2 is the fourth order Ljung-Box test for squared standardized residuals
Q_{12}^2 is the 12th order Ljung-Box test for squared standardized residuals.
Critical values for the fourth and 12th order Ljung-Box tests at 5% significance levels are 9.48 and 21.02, respectively.
See also notes to Table 3.

Table 6. Bivaraite Granger causality tests among inflation, inflation uncertainty and output uncertainty

	Countries									
	BG	HR	CZ	HU	LT	MC	PL	RO	SK	SI
Panel A. H0: Inflation rate does not Granger cause inflation uncertainty										
4 Lags	**1.596**	(+)1404.087*	(+)32.160*	(+)50.377*	1.819	(+)19.795*	(+)160.913*	(+)43.018*	(+)91.008*	0.231
8 Lags	1.742	**(+)1320.794***	(+)14.452*	(+)27.435*	**0.983**	(+)43.882*	(+)119.537*	(+)35.122*	**(+)47.339***	0.243
12Lags	(+)1.837***	(+)1572.631*	**(+)11.928***	**(+)17.279***	1.211	**(+)18.414***	**(+)89.681***	**(+)29.352***	(-)37.611*	**0.982**
Panel B. H0: Inflation uncertainty does not Granger cause inflation rate										
4 Lags	**(-)2.465*****	(-)5.011*	(+)2.271***	(+)4.536*	**0.341**	0.436	(-)10.814*	(-)3.028**	1.011	**1.645**
8 Lags	1.125	(-)4.940*	(-)1.809***	**(+)4.142***	0.700	1.712	(-)12.646*	1.414	(-)2.679*	1.183
12Lags	1.439	**(-)5.250***	**(-)2.562****	(+)2.655*	0.630	**(+) 2.392****	**(-)9.935***	**1.237**	**(-)1.933****	1.093
Panel C. H0: Inflation rate does not Granger cause output uncertainty										
4 Lags	(+)2.072***	(+)65.600*	0.398	(+)2.452**	(+)2.108***	1.318	0.568	1.071	0.601	0.364
8 Lags	1.412	**(+)32.636***	0.568	1.046	(+)1.768***	0.941	1.604	0.971	0.436	0.546
12Lags	**1.390**	(+)20.718	**0.854**	**0.979**	**1.907**	**1.075**	**0.876**	**1.298**	**0.444**	**0.678**
Panel D. H0: Output uncertainty does not Granger cause inflation rate										
4 Lags	**(-)2.594****	**0.683**	**0.512**	**0.473**	0.965	0.840	**(+)6.258***	1.477	0.106	**0.830**
8 Lags	1.681	0.182	0.486	0.337	1.245	1.085	(+)11.851*	1.264	**0.926**	0.849
12Lags	(-)3.588*	0.174	0.682	1.116	**1.472**	**(+)1.732*****	(+)8.101*	**1.486**	0.736	0.823

See Notes to Table 3. *,**,*** denote significance at 1%, 5%, and 10% significance levels, respectively. Boldface denotes optimal lag length selected by the Akaike Information Criterion.

Table 7. Bivaraite Granger causality tests among output growth, inflation uncertainty and output uncertainty

	Countries									
	BG	HR	CZ	HU	LT	MC	PL	RO	SK	SI
Panel A. H0: Inflation uncertainty does not Granger cause output growth										
4 Lags	**0.273**	(-)2.785**	1.691	**(-)2.093*** **	**0.690**	0.608	0.206	**(-)3.608***	**0.525**	**0.378**
8 Lags	0.481	(-)1.822***	1.622	0.570	0.942	0.919	(-)2.221**	(-)2.029**	0.466	0.641
12Lags	(+)1.704**	**(-)2.783** **	**1.159**	0.686	1.393	**0.991**	**(-)5.379***	(+)1.917**	0.575	0.882
Panel B. H0: Output uncertainty does not Granger cause output growth										
4 Lags	**1.208**	**(-)4.256***	**0.347**	(-)2.291***	(+)4.419*	(-)3.224**	(-)3.125**	1.310	0.326	**1.432**
8 Lags	(+)1.827***	(-)3.038*	1.388	**1.489**	(+)3.655*	(+)3.404*	**(-)5.382***	1.239	**0.265**	0.593
12Lags	1.423	(-)2.394*	1.561	1.389	**(+)2.654** **	**(+)2.244** **	(-)4.450*	**1.516**	0.836	0.512
Panel C. H0: Output growth does not Granger cause output uncertainty										
4 Lags	**(-)6.648***	(+)4.908*	(-)2.399**	(-)16.150*	(-)4.529*	(-)8.778*	(-)3.212**	(-)3.681*	0.909	**(-)11.698***
8 Lags	(-)3.568*	(+)2.795*	1.444	**(-)9.054***	(-)5.635*	(+)5.635*	(-)4.238*	(-)1.798***	0.616	(-)6.028*
12Lags	(-)2.083**	**(+)2.193** **	**1.349**	(-)6.097*	**(-)4.346***	**(+)2.993***	**(-)2.714***	**(-)2.249** **	**0.750**	(-)4.278*
Panel D. H0: Output growth does not Granger cause inflation uncertainty										
4 Lags	1.772	0.996	0.542	(-)3.060*	0.915	1.171	(-)4.317*	0.252	0.269	(-)4.262*
8 Lags	1.369	0.420	1.270	**(-)2.801***	0.848	1.575	**(-)3.149***	0.861	**0.845**	**(-)3.197***
12Lags	**1.110**	**1.569**	**1.048**	(-)2.250**	**1.537**	**0.931**	(-)5.062*	**0.852**	0.810	(-)2.491*

See Notes to Table 3. *,**,*** denote significance at 1%, 5%, and 10% significance levels, respectively. Boldface denotes optimal lag length selected by the Akaike Information Criterion.

Table 8. Bivaraite Granger causality tests among inflation and output growth rates and their uncertainties

	Countries									
	BG	HR	CZ	HU	LT	MC	PL	RO	SK	SI
Panel A. H0: Inflation rate does not Granger cause output growth										
4 Lags	0.527	1.024	0.609	0.756	0.769	(-)2.982**	(-)9.106*	(-)2.615**	0.099	(-)2.080***
8 Lags	**1.248**	(-)1.818**	1.322	0.648	**(+)1.932*****	(-)1.956***	(-)7.576*	**(-)1.906*****	0.079	1.453
12Lags	1.060	**(-)3.154***	**0.934**	**0.562**	(+)1.912**	**1.214**	**(-)8.148***	(-)1.749***	**0.274**	**1.336**
Panel B. H0: Output growth does not Granger cause inflation rate										
4 Lags	**0.573**	0.372	0.378	0.656	1.389	1.749	1.234	(+)2.770**	0.160	0.312
8 Lags	0.582	0.247	**(+)1.785*****	**0.874**	(+)1.834***	(+)1.846***	(-)2.210**	1.415	**0.757**	**0.207**
12Lags	1.144	**(-)1.883****	1.486	0.744	**1.258**	**(+)2.306****	**(-)4.031***	**1.024**	0.953	0.401
Panel C. H0: Output uncertainty does not Granger cause inflation uncertainty										
4 Lags	(+)4.985*	**(-)13.421***	**0.554**	(+)6.349*	**1.153**	0.535	**(+)19.886***	(+)2.943*	0.965	**0.394**
8 Lags	(+)3.083*	(-)6.714*	0.346	**(+)3.792***	1.140	0.868	(+)23.348*	1.591	**0.627**	(-)2.561**
12Lags	**(+)3.878***	(-)4.367*	0.419	(+)2.260**	(-)1.686***	**0.606**	(+)16.729*	**(+)2.894***	0.949	(-)1.921***
Panel D. H0: Inflation uncertainty does not Granger cause output uncertainty										
4 Lags	0.818	(+)29.044*	0.625	**1.331**	**0.688**	0.264	0.597	**1.450**	**0.366**	1.013
8 Lags	0.796	(+)14.973*	**0.832**	(+)2.379**	1.098	0.695	0.811	(+)1.704***	0.428	**1.017**
12Lags	**(-)2.029****	**(+)10.472***	0.905	1.366	1.073	**1.160**	**0.848**	1.355	0.422	0.908

See Notes to Table 3. *,**,*** denote significance at 1%, 5%, and 10% significance levels, respectively. Boldface denotes optimal lag length selected by the Akaike Information Criterion.

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