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Macroeconomic Uncertainty and Performance in Asian Countries

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Abstract

We use a very general bivariate GARCH-M model and quarterly data for five Asian countries to test for the impact of real and nominal macroeconomic uncertainty on inflation and output growth. We conclude the following. First, in the majority of countries uncertainty regarding the output growth rate is related negatively to the average growth rate. Second, contrary to expectations, inflation uncertainty in most cases does not harm the output growth performance of an economy. Third, inflation and output uncertainty have a mixed effect on inflation. Consistent results are found using the VAR-GARCH-M approach to investigate the dynamic relationship between inflation and output growth using impulse response functions. This evidence implies that macroeconomic uncertainty may even improve macroeconomic performance, i.e., raise output growth and reduce inflation. Our empirical results highlight important differences with those for industrialized countries.

Keywords: Inflation, Output growth, Uncertainty, GARCH models
JEL Classification: C22, C51, C52, E0

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1 Introduction

Macroeconomists have long debated the issue of the welfare costs of inflation both at the theoretical and empirical level. It is a common belief that the recent emphasis on price stability, expressed for practical purposes as low and stable inflation, among the world's major central banks, including the Fed and the European Central Bank (ECB), is predicated on the assumed adverse impact of inflation on economic efficiency. It is widely accepted that the focus of monetary policy on price stability is the main cause of the low inflation rates achieved by several industrialized countries (Greenspan, 2004). The emphasis on price stability in industrialized countries in the last fifteen years has recently been prioritized in several East Asian countries, including South Korea, the Philippines, Singapore and Thailand (McCauley, 2001).

Theoretically speaking, the direction of the impact of the average rate of inflation on the rate of economic growth is quite ambiguous (Orphanides and Solow, 1990). In addition, the impact of inflation on output growth may take place indirectly, via the inflation uncertainty channel. Friedman (1977) in his Nobel lecture claims that a higher average rate of inflation raises uncertainty about future inflation (the first part of his hypothesis), it distorts the effectiveness of the price mechanism in allocating resources efficiently, and thus it creates economic inefficiency and a lower level of output (the second part of his hypothesis). Moreover, inflation uncertainty by affecting interest rates also impacts on the intertemporal allocation of resources. In this light, a comprehensive empirical study that tests for the real effects of inflation should control for the impact of inflation uncertainty on output. The positive correlation between inflation and inflation uncertainty reported in empirical studies can also arise from a positive causal effect of inflation uncertainty on inflation. Cukierman and Meltzer (1986) provide a theoretical model that explains such a causal effect. In the presence of more inflation uncertainty, less conservative central bankers hoping for output gains have an incentive to surprise the public and generate unanticipated inflation.

The empirical investigation of the relationship between inflation uncertainty on the one hand and macroeconomic performance (inflation and output growth) on the other hand requires a proxy for the unobserved variable of uncertainty. Early studies measured uncertainty by the moving standard deviation of the inflation series and hence failed to distinguish between anticipated and unanticipated changes (the source of uncertainty) in inflation as this measure captures the variability of inflation (a wider concept than uncertainty). The development of Generalised Autoregressive Conditional Heteroskedasticity (GARCH) techniques allows the measurement of inflation uncertainty by the conditional variance of shocks to the inflation series and more accurate testing of the two parts of the Friedman hypothesis (e.g., Baillie et al., 1996, Grier and Perry, 1998, 2000).

Macroeconomic uncertainty due to the variability in output growth may also affect the output growth rate. Macroeconomic analysis before the 1980s treated the theories of the business cycle (and its variability) and economic growth independently. However, a number of theories have raised questions on the assumption of independence between the variability of the business cycle and economic growth (Bernanke, 1983; Black, 1987; Pindyck, 1991; Blackburn and Pelloni, 2005). Recent evidence corroborates these theoretical findings (Caporale and McKiernan, 1996, 1998; Henry and Olekalns, 2002, Fountas et al., 2006).

From the econometric methodology point of view, the impact of macroeconomic uncertainty (proxied by the conditional variance of shocks to the inflation or output growth series) on macroeconomic performance can be examined in various ways. First, a univariate GARCH framework may be employed where the conditional variances of inflation and output growth are estimated independently from each other and then Granger causality tests are performed to examine the relationships between pairs of variables. Alternatively, a simultaneous approach can be adopted where a bivariate GARCH-in-mean (GARCH-M) model is estimated to provide estimates of the conditional variances and at the same time test for the impact of uncertainty on macroeconomic performance. This approach, adopted in the present work, has been applied recently by Grier et al. (2004) and Bredin and Fountas (2005) for the US economy and the G7, respectively. However, our paper makes an interesting addition to this literature by estimating the impulse response functions from a VAR-GARCH-M model that has a structural interpretation.

In this paper, the relationship between macroeconomic uncertainty and performance is investigated empirically with the use of a bivariate GARCH-M model for five Asian countries on which relatively long series on inflation and growth data are available. Some of these countries are classified as developing; however no claim is made that our results apply for all developing countries. Given the recent adoption of the price stability objective by some of these countries (McCauley, 2001), it would be interesting to examine whether such an emphasis on price stability has a basis in the real costs of inflation. Some of the countries in our study, in particular India and the Philippines, are at early stages of institutional and financial development relative to industrialized countries. This leads us to expect a different impact of macroeconomic uncertainty on inflation and growth relative to the industrialized countries, as explained below. Four hypotheses are tested: they concern the impact of inflation and growth uncertainty on inflation and growth.

Our results are likely to have important implications for policymaking. In particular, the recent emphasis on price stability by many central banks around the world is predicated on the adverse effects of inflation on economic efficiency and growth. Some of these effects, as Friedman (1977) has argued, take place via changes in inflation uncertainty. It is, therefore, important to test for whether inflation uncertainty is indeed costly. Moreover, the emphasis on stabilising inflation may be associated with large variability in output growth and hence more uncertainty regarding the growth rate (the so-called Taylor effect predicting a trade-off between variability in inflation and output growth). This increasing output uncertainty may be linked with less output growth, thus making the empirical testing of such a hypothesis an interesting task. Our results on the effects of nominal and real uncertainty on output growth will therefore have important implications for the choice of inflation versus output stabilisation on the part of the central banks of these countries. Moreover, the Asian countries in our empirical analysis represent a good testing ground for the relationship between macroeconomic uncertainty and performance owing to the sharp rise in uncertainty in some of these countries following the financial crisis of 1997-98. According to some economists (McCauley, 2001), this crisis represented a watershed in monetary policymaking in the region and led to new objectives and institutions for central banking.

The paper is structured as follows. Section 2 provides a summary of the theoretical literature on the relationship between macroeconomic uncertainty and performance. Section 3 summarises the empirical literature which refers mainly to industrialized countries. Section 4 outlines our econometric methodology. Section

5 presents the results and an extension to a structural VAR model augmented with GARCH effects. This section also discusses our results and relates them to some recent studies. Finally, Section 6 summarises our main conclusions.

2 Theory

According to Friedman (1977) inflation may affect the real economy via its impact on inflation uncertainty. Friedman's argument contains two parts. In the first leg of the Friedman hypothesis, an increase in inflation may induce an erratic policy response by the monetary authority and therefore lead to more uncertainty about the future rate of inflation. In the second leg of the Friedman hypothesis, the increasing uncertainty about inflation distorts the effectiveness of the price mechanism in allocating resources efficiently, thus leading to negative output effects. Friedman's argument represents one of the few existing arguments on the rationalisation of the welfare effects of inflation.

The second part of Friedman's hypothesis predicts that increased inflation uncertainty would increase the observed rates of unanticipated inflation and hence will be associated with the costs of unanticipated inflation. Such costs arise from the effect of inflation uncertainty on both the intertemporal and intratemporal allocation of resources. The effect of inflation uncertainty on output growth has been addressed formally by Dotsey and Sarte (2000). In a cash-in-advance model that allows for precautionary savings and risk aversion, they show that more inflation uncertainty can have a positive output growth effect. According to the authors' argument, an increase in the variability of monetary growth, and therefore inflation, makes the return to money balances more uncertain and leads to a fall in the demand for real money balances and consumption. Hence, agents increase precautionary savings, and the pool of funds available to finance investment increases. It is anticipated that this argument is more likely to apply for industrialised countries with highly-developed banking and financial systems where the increase in savings is more likely to be channelled to more investment projects, thus facilitating the growth prospects of the economy.

The literature examines also the impact of a change in inflation uncertainty on the average rate of inflation, i.e., the opposite causal effect to that predicted by Friedman. In a Barro-Gordon set up where agents face uncertainty about the rate of monetary growth, Cukierman and Meltzer (1986) show that the policymaker applies an expansionary monetary policy to surprise the agents and enjoy output gains. The so called Cukierman and Meltzer hypothesis predicts a positive causal effect from inflation uncertainty to inflation[1].

The effect of output growth uncertainty on inflation is examined by Devereux (1989) who enriches the Barro-Gordon model with endogenous wage indexation. He considers the impact of an exogenous increase in real (output) uncertainty on the degree of wage indexation and the optimal inflation rate delivered by the policymaker. More real uncertainty reduces the optimal amount of wage indexation and induces the policymaker to engineer more inflation surprises in order to obtain favourable real effects. From a theoretical point of view, it is possible for more output uncertainty to reduce inflation. Higher output uncertainty reduces inflation uncertainty[2] and, therefore, the rate of inflation, according to the Cukierman-Meltzer hypothesis. Hence, the testable implication of these two effects combined is that more output growth uncertainty should lead to a lower rate of inflation.

The effect of output uncertainty on output growth has received considerable attention in the theoretical macroeconomic literature without a consensus reached on the direction of this effect. Three scenarios are possible regarding the impact of output variability on output growth. First, there is the possibility of independence between output variability and growth. In other words, the determinants of the two variables are different from each other. For example, according to some business cycle models, output fluctuations around the natural rate are due to price misperceptions in response to monetary shocks. On the other hand, changes in the growth rate of output arise from real factors such as technology. The scenario of a negative association between output variability and average growth relates to Keynes (1936) who argued that entrepreneurs, when estimating the return on their

[1] Holland (1995) has provided an argument that predicts the opposite effect in the causal relationship, i.e., a negative effect of inflation uncertainty on inflation, the so-called "stabilising Fed hypothesis". He claims that, as inflation uncertainty rises due to increasing inflation, the monetary authority responds by contracting money supply growth, in order to eliminate inflation uncertainty and the associated negative welfare effects.

[2] The negative association between inflation and output variability is known in the literature as the Taylor effect.

investment, take into consideration the fluctuations in economic activity. The larger the output fluctuations, the higher the perceived riskiness of investment projects and, hence, the lower the demand for investment and output growth[3]. Finally, the possibility of a positive impact of output variability on growth has been put forward by Black (1987) who argues that investments in riskier technologies will be pursued only if the expected return on these investments (average rate of output growth) is large enough to compensate for the extra risk. As real investment takes time to materialize, such an effect would be more likely to obtain in empirical studies utilizing low-frequency data. A number of recent studies based on endogenous growth caused by learning-by-doing also examine the relationship between output variability and growth. Blackburn and Pelloni (2005) examine the correlation between average output growth and its variability in an endogenous growth setup and show the correlation is negative.

3 The Empirical Evidence

The existing empirical literature on the relationship between macroeconomic uncertainty and performance applies mainly to industrialized countries. The first empirical studies that addressed the relationship between inflation and its uncertainty proxied inflation uncertainty by the variance (or standard deviation) of inflation, thus effectively measuring inflation variability rather than uncertainty. Following the seminal work on the ARCH model, inflation uncertainty is often measured by the conditional variance of the inflation process. Most studies test for the effect of inflation on inflation uncertainty. The evidence on the impact of inflation uncertainty on growth is more limited. Some of this literature is summarised in Holland (1993). GARCH studies of this issue are mostly based on US data (e.g., Coulson and Robins, 1985; Jansen, 1989; Grier and Perry, 2000, Grier et al., 2004). Some exceptions are Bredin and Fountas (2005) and Fountas et al. (2006). The evidence is rather mixed. Grier and Perry (2000) and Grier et al. (2004) find evidence for a negative effect. In contrast, Coulson and Robins (1985) and Jansen (1989) find evidence for a positive and zero effect, respectively. Fountas et al. (2006) find mixed evidence using a two-step approach that combines the estimation of a

[3]According to Bernanke (1983) and Pindyck (1991), the negative relationship between output volatility and growth arises from investment irreversibilities at the firm level.

GARCH model with the implementation of Granger-causality tests. Finally, Elder (2004) applies a richly specified 4-variable structural VAR with MGARCH to US data and finds that inflation uncertainty tends to depress output growth.

A number of recent studies focus on the causal impact of inflation uncertainty on inflation using the GARCH approach (Baillie et al., 1996, Grier and Perry, 1998, 2000, Grier et al., 2004). Grier and Perry (2000) and Grier et al. (2004) use only US data, whereas the rest of the studies use international data. In general, the evidence is mixed. Baillie et al. (1996) find evidence supporting the link between the two variables for the UK and some high-inflation countries, whereas Grier and Perry (1998) in their G7 study find evidence in favour of the Cukierman-Meltzer hypothesis for some countries and in favour of the Holland hypothesis for other countries. Finally, Grier and Perry (2000) and Grier et al. (2004) find evidence for a zero and negative effect of inflation uncertainty on inflation in the US, respectively.

The empirical evidence to date on the association between output variability and output growth is mixed. Evidence for a positive effect is obtained by Kormendi and Meguire (1985) and Grier and Tullock (1989) and evidence for a negative effect by Ramey and Ramey (1995). Empirical evidence on the causal effect of output growth uncertainty (as opposed to variability) on output growth has appeared only recently. Caporale and McKiernan (1996, 1998) obtain evidence of a positive causal effect using UK and US data, respectively, supporting the Black hypothesis. Henry and Olekalns (2002) and Grier et al. (2004) find US evidence for a negative and positive effect, respectively. Finally, few studies test for the Devereux hypothesis but find no US evidence (Grier and Perry (2000) and Grier et al. (2004)).

4 Econometric Methodology

We allow for the interaction among inflation, growth, inflation uncertainty, and growth uncertainty by modelling inflation (π_t) and growth (y_t) simultaneously in a VARMA (vector autoregressive moving average) GARCH-M model (see Grier et al., 2004) shown by equations (1) and (2) below. This approach simultaneously estimates equations for both inflation and output growth and takes into account the conditional standard deviations as explanatory variables. The standard information criteria, Schwartz (SBC) and Akaike (AIC) are used to test for the lag length for both p and q. Equation (1) below shows a VARMA model for inflation and growth enriched by the conditional standard deviations of inflation and growth.

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi \sqrt{H_t} + \sum_{j=1}^{q} \Theta_j \epsilon_{t-j} + \epsilon_t \quad where\ \epsilon_t \sim (0, H_t) \tag{1}$$

$$H_t = \begin{pmatrix} h_{y,t} & h_{y\pi,t} \\ h_{\pi y,t} & h_{\pi,t} \end{pmatrix}$$

$$where \quad Y_t = \begin{pmatrix} y_t \\ \pi_t \end{pmatrix}; \epsilon_t = \begin{pmatrix} \epsilon_{y,t} \\ \epsilon_{\pi,t} \end{pmatrix}; \mu = \begin{pmatrix} \mu_y \\ \mu_\pi \end{pmatrix}$$

$$\Gamma_i = \begin{pmatrix} \Gamma_{11}^{(i)} & \Gamma_{12}^{(i)} \\ \Gamma_{21}^{(i)} & \Gamma_{22}^{(i)} \end{pmatrix}; \Psi = \begin{pmatrix} \Psi_{11} & \Psi_{12} \\ \Psi_{21} & \Psi_{22} \end{pmatrix}; \Theta_j = \begin{pmatrix} \Theta_{11}^{(j)} & \Theta_{12}^{(j)} \\ \Theta_{21}^{(j)} & \Theta_{22}^{(j)} \end{pmatrix}$$

where $\epsilon_t \mid \Omega_t \sim (0, H_t)$, and Ω_t is the information set available at time t.

Equation (2) represents the conditional variance-covariance matrix for the shocks to inflation and growth.

$$H_t = C_0^{*'} C_0^* + B_{11}^{*'} H_{t-1} B_{11}^* + A_{11}^{*'} \epsilon_{t-1} \epsilon_{t-1}' A_{11}^* + D_{11}^{*'} \xi_{t-1} \xi_{t-1}' D_{11}^* \tag{2}$$

$$where \quad C_0^* = \begin{pmatrix} c_{11}^* & c_{12}^* \\ 0 & c_{22}^* \end{pmatrix}; B_{11}^* = \begin{pmatrix} \beta_{11}^* & \beta_{12}^* \\ \beta_{21}^* & \beta_{22}^* \end{pmatrix}; A_{11}^* = \begin{pmatrix} \alpha_{11}^* & \alpha_{12}^* \\ \alpha_{21}^* & \alpha_{22}^* \end{pmatrix};$$

$$D_{11}^* = \begin{pmatrix} \delta_{11}^* & \delta_{12}^* \\ \delta_{21}^* & \delta_{22}^* \end{pmatrix}; \xi_t^2 = \begin{pmatrix} \xi_{y,t}^2 \\ \xi_{\pi,t}^2 \end{pmatrix}$$

The positive definiteness of the conditional variance justifies the quadratic form in equation (2). The model is estimated using maximum likelihood subject to H_t being positive definite. The GARCH-M approach is adopted in order to take account of the possible influence of uncertainty about output growth and inflation on average growth and inflation. The effects of nominal and real uncertainty are captured by the elements of Ψ. Ψ_{11} and Ψ_{21} test for the impact of output growth uncertainty on output growth and the inflation rate, respectively. Positive and significant values for these two coefficients would lend support to the Black and Devereux hypotheses, respectively. Ψ_{12} and Ψ_{22} test for the impact of inflation uncertainty on output growth and the inflation rate, respectively. Negative and positive values for these two coefficients would lend support to the Friedman and Cukierman-Meltzer hypotheses, respectively.

Equation (2) is the standard BEKK model (Engle and Kroner, 1995) augmented with the final term to take account of possible asymmetry of the impact of shocks on the conditional variances. An important distinction between the approach adopted here and the vast majority of previous studies is that the present model takes account of possible non-diagonality and asymmetry in the covariance structures. In this sense, the model follows Grier et al. (2004) who test for, rather than assume, diagonality and symmetry using US data. The chosen model is rich enough to allow us to answer the following questions. First, does the volatility in one series spillover into the volatility of another series? In equation (2), such a volatility spillover would imply a nondiagonal covariance process. In other words, it requires that the off-diagonal elements of the A_{11}^{*}, B_{11}^{*} and D_{11}^{*} matrices be jointly significant. Therefore, assuming a priori diagonality may lead to potentially serious problems as persistence in the conditional variance may be ignored. Second, does *bad news* lead to greater volatility than *good news*? Specifically, bad news in terms of inflation (output growth) taken as higher (lower) than expected inflation (output growth) will correspond to a positive (negative) residual. We set the model up in such a way that $\xi_{\pi,t}$ be the $\max(\epsilon_{\pi,t}, 0)$ capturing the positive innovations regarding inflation or *bad news*. Let $\xi_{y,t}$ be the $\min(\epsilon_{y,t}, 0)$ capturing the negative innovations regarding output growth or *bad news*. In the absence of asymmetry, the coefficient matrix D_{11}^{*} would be statistically insignificant and equation (2) would be reduced down to the symmetric BEKK model (Engle and Kroner, 1995).

5 Data and Results

5.1 Data

We use quarterly data on the Industrial Production Index (IPI) and the Consumer Price Index (CPI) as proxies for output and the price level, respectively. The data refer to five Asian countries, namely, India, South Korea, Malaysia, Philippines and Singapore, and have different starting dates[4]. The sample ends in the first quarter of 2005 in all cases, except for India and the Philippines where it ends in the last quarter of 2004. The choice of these five countries is based on data availability considerations. All data are taken from the International Financial Statistics published by the IMF. We measure inflation by the annualized quarterly difference of the logarithm of the price index PI [$\pi_t = \log(\frac{\mathrm{PI}_t}{\mathrm{PI}_{t-1}}) \times 400$] and real output growth by the annualized quarterly difference in the logarithm of the IPI [$y_t = \log(\frac{\mathrm{IPI}_t}{\mathrm{IPI}_{t-1}}) \times 400$].[5] We first test for the stationarity properties of our data using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results of these tests indicate that we can treat the inflation rate and the growth rate of industrial production in each country as stationary processes. [6]

5.2 Results

We estimate the model of equations (1) and (2) using the quasi-maximum likelihood estimation proposed by Bollerslev and Wooldridge (1992) to account for possible non-normality of the error term.[7] Following the estimation, we test for various nested models and report the results of these specification tests in Table 1. On the basis of these results we conclude the following. First, the statistical significance of the A^*_{11}, B^*_{11} and D^*_{11} matrices provides evidence for heteroskedastic conditional variances. The results of Table 1 indicate that these three matrices are jointly significant at the 1% level. Second, the joint statistical significance of the off-diagonal elements of the same three matrices indicates that lagged conditional variances and lagged squared innovations in inflation (output growth), tend to affect the conditional variances of output growth (inflation). More specifically, the joint significance of the off-diagonal elements of the A^*_{11} and D^*_{11} matrices at 1% implies that shocks

[4]The sample begins in 1963.1 for India, 1966.1 for Singapore, 1970.1 for South Korea and Malaysia and 1981.1 for Philippines. Summary statistics are given in an appendix available on request.

[5]In our empirical analysis we take account of possible seasonality and structural breaks in the data. We find no evidence of a structural break on either inflation or output growth during the period of the financial crisis 1997-98. Although a number of the countries in our sample were effected considerably by the financial crisis, our quarterly data set is not influenced by the events.

[6]Plots of inflation and growth rates and unit root test results are available from the authors upon request.

[7]The lag length is set to 4 in each country case.

to inflation or output growth tend to influence with a lag the uncertainty about the other macroeconomic variable, i.e., output growth or inflation. Third, the joint significance of the elements of the D_{11}^{*}matrix at 1% leads us to conclude that the covariance process is asymmetric in all countries. Finally, the joint significance of the elements of the Ψ matrix indicates the presence of GARCH-M effects[8].

We now focus our attention on the statistical significance and signs of the elements of matrix Ψ in order to test for the four economic hypotheses presented in section 2 regarding the impact of macroeconomic uncertainty on macroeconomic performance, namely inflation and output growth. The estimates of Ψ and the associated standard errors are reported in Table 2. Our results on these hypotheses are summarised as follows. First, regarding the effect of output uncertainty on output growth, we find evidence for a negative effect in three countries (Singapore at 10%, the Philippines and South Korea at 5%) and no effect in two countries (India and Malaysia). Hence, there is no evidence from our sample of countries for Black's hypothesis. Second, output growth uncertainty does not have a positive impact on inflation as predicted by the Devereux hypothesis. The only exception is India. Third, contrary to Friedman's argument, we find evidence that in all countries, inflation uncertainty does not harm growth. It is interesting to note that in four of the countries in our sample (South Korea, Philippines and Singapore at 5% and Malaysia at 10%) inflation uncertainty tends to enhance growth, thus supporting the theory of Dotsey and Sarte (2000). Fourth, we obtain mixed evidence regarding the effect of inflation uncertainty on inflation: the effect is negative in three cases, positive in one and zero in the other country. On the basis of these results, we conclude that real uncertainty is quite costly in terms of loss in output growth but does not seem to be associated with an increase in inflation. In contrast, nominal uncertainty does not seem to be costly in terms of lower output growth or higher inflation. In summary, these results point to the conclusion that macroeconomic uncertainty does not have an adverse impact on performance in most cases. It is noteworthy that uncertainty may even improve the performance of some economies, assuming, of course, this performance is evaluated in terms of output growth and the rate of inflation.

[8] The values of the Ljung-Box statistics indicate the absence of serial correlation up to 4^{th} and 12^{th} order in the standardised and squared standardised residuals in both the inflation and output growth equations. These results are available upon request.

5.3 A VAR-GARCH-M model

As a further sensitivity test of the results we now investigate the dynamic relationship between inflation and output growth using a VAR-GARCH-M and the resulting impulse response functions. Estimating the dynamic effect of, for example, a shock to inflation on output growth can be addressed within a generalized version of the VAR framework introduced by Sims (1980) and Bernanke (1986). The standard VAR can be modified to accommodate multivariate GARCH errors and to allow the conditional variance to affect the conditional mean. In particular, we estimate the empirical model developed in Elder (1995, 2004). The operational assumption is that the dynamics of the structural system can be summarized by a linear function of the variables of interest, so that the structural system can be represented as;

$$\mathbf{B}Y_t = \mu + \Gamma_1 Y_{t-1} + \Gamma_2 Y_{t-2} + ... + \Gamma_p Y_{t-p} + \Psi\sqrt{H_t} + \epsilon_t \quad (3)$$

$$H_t = C_0^{*'} C_0^* + B_{11}^{*'} H_{t-1} B_{11}^* + A_{11}^{*'} \epsilon_{t-1}\epsilon_{t-1}' A_{11}^* \quad (4)$$

$$where \quad C_0^* = \begin{pmatrix} c_{11}^* & c_{12}^* \\ 0 & c_{22}^* \end{pmatrix}; B_{11}^* = \begin{pmatrix} \beta_{11}^* & \beta_{12}^* \\ \beta_{21}^* & \beta_{22}^* \end{pmatrix}; A_{11}^* = \begin{pmatrix} \alpha_{11}^* & \alpha_{12}^* \\ \alpha_{21}^* & \alpha_{22}^* \end{pmatrix}$$

All variables are defined as previously, with the exception of matrix $\mathbf{B}$, where $\dim(\mathbf{B}) = \dim(\Gamma_i) = (\mathrm{N} \times \mathrm{N})$. Equation (4) shows the conditional variance-covariance matrix for inflation and output growth shocks and is similar to equation (2) referred to in our original model. The only difference is that the conditional variance-covariance matrix in the present case is symmetric. In order to estimate equation (3), we must impose restrictions on the matrix $\mathbf{B}$ consistent with the structural interpretations for output growth and inflation. Identification of the structural parameters in VARs requires minimal structure to be imposed on the dynamics of the system, such as N(N-1)/2 exclusion restrictions on the matrix $\mathbf{B}$, subject to a rank conditional, and assuming that the structural disturbances ϵ_t are uncorrelated (cf. Bernanke (1986)). In particular, we allow inflation to affect output contemporaneously, but we assume that inflation responds to output only with a lag. Hence, the assumption that H_t is diagonal follows naturally from the orthogonalization typically applied to VARs. As with the usual VAR, the reduced form covariance matrix $\mathbf{B}^{-1}H_t\mathbf{B}^{-1'}$ will not, in general, be diagonal. Elder (1995, 2004) shows that such an orthogonalization of the structural errors substantially reduces the requisite number of variance functions parameters if the structural coefficients are estimated directly. If we assume also that the conditional variance of $y_{i,t}$ depends only on its own past squared errors and its own past conditional variances, then the parameter matrices B^* and A^* are also diagonal. All parameters of the variance function are estimated jointly by full information maximum likelihood, and to facilitate estimation, we alternatively allow output and inflation volatility to enter the inflation equation and the output equation. We also allow a full one year of lags in each VAR to capture relevant dynamics.

The results of the estimation of the VAR-GARCH-M model are reported in Table 3. We report estimates of the in-mean coefficients (elements of matrix Ψ) and their standard errors. These results, in comparison with those in Table 2, confirm in most cases the conclusions reached in the previous section. In particular, with the exception of one coefficient, the signs of the estimated in-mean coefficients are exactly the same as previously. The only differences that apply relate to the statistical significance of these coefficients. Nevertheless, the implications of these results for the relationship between macroeconomic uncertainty and performance are broadly speaking the same. First, the negative impact that real uncertainty has on growth remains consistent. Second, there is less evidence in favor of the Dotsey and Sarte (2000) theory, now only two countries, that inflation uncertainty tends to enhance growth. Third, the evidence for Devereux or in fact any real uncertainty inflation link remains unimportant. Finally, we again find mixed evidence regarding the effect of inflation uncertainty on inflation in the case of all five countries, with the Philippines the only country with a statistically significant (negative) effect. On the basis of these results from the structural model, we conclude that real uncertainty seems to be considerably more costly than nominal uncertainty in terms of its impact on growth.

The relevant impulse response functions are reported in Figure 1. The impulse response functions are derived from the infinite order moving average representation as in Elder (1995, 2003), with errors bands constructed as described in Elder and Serletis (2007). For the Philippines, Malaysia and Singapore, output growth tends to increase in response to an inflation shock, before decreasing after about one year. For South Korea and India, the effect of an inflation shock on output growth is primarily negative in the first year before turning positive after about one year. Note that in each case the impulse-responses are not estimated very precisely, lying within the 90% confidence interval of zero. Given the nature of these rapidly developing economies, it may not be surprising that inference from these VARs is imprecise, compared that for developed economies such as the United States. Despite the relatively flexibility of VARs, the assumption of a constant bivariate structural relationship in output and inflation over the relevant sample may indeed be tenuous, and the results should be interpreted with this in mind.

5.4 Discussion of Results and Related Recent Literature

Our results carry noteworthy implications for macroeconomic modelling and policymaking. The empirical results find that in three of the five countries output uncertainty and output growth are related suggesting that macro theorists should incorporate the analysis of output uncertainty into growth models, along the lines of recent research by Blackburn and Pelloni (2005). Moreover, in all of our sample countries where output uncertainty and growth are related, we find that output uncertainty is a negative determinant of output growth, thus supporting Pindyck (1991), among others. This result contrasts with the evidence obtained in other studies for industrialized countries which indicates that for several countries growth uncertainty has a positive impact on growth (e,g., Bredin and Fountas, 2005). As far as the causal effect of output uncertainty on the inflation rate is concerned, our time series evidence provides little support to the Devereux hypothesis. It should be emphasized that the available empirical studies on the Devereux hypothesis are rather limited and include mainly US data. To the best of our knowledge the present study, Bredin and Fountas (2005) and Fountas et al. (2006) are the only exceptions.

Regarding the impact of nominal (inflation) uncertainty on output growth, our empirical results find evidence against the hypothesis advanced by Friedman that uncertainty about inflation is detrimental to growth (the exception perhaps being India). It is noteworthy that in Singapore and South Korea we find evidence for a positive effect of inflation uncertainty on growth, thus supporting Dotsey and Sarte

(2000). Hence, in some countries, inflation uncertainty seems to be a contributing factor to growth. As said earlier, it is interesting to note that the argument advanced by Dotsey and Sarte (2000) is more relevant for developed countries where the banking system is at an advanced stage and financial markets are well developed. Singapore and South Korea do represent countries with developed financial markets and banking sector, thus justifying the evidence for the Dotsey and Sarte effect in these countries[9]. The mixed results relating to the impact of inflation uncertainty on growth across Asian countries is consistent with previous results for industrialized countries (Bredin and Fountas, 2005). The early literature (Holland,1993), reports mixed results that are sensitive to factors such as the measure of inflation uncertainty, the chosen econometric methodology, the countries examined, and the sample period. Finally, it may also be the case that our model is capturing a positive correlation, in reduced form, between inflation volatility and the growth rate of real output. Hence, our measure of inflation volatility may tend to be high when output growth is high, so that inflation uncertainty proxies for some omitted third variable driving output growth. As far as the effect of nominal uncertainty on inflation is concerned, our country-specific evidence on the Cukierman-Meltzer hypothesis is anticipated given that national central banks adjust their rate of money growth differently to inflation uncertainty depending on their relative preference towards inflation and output stabilisation.

To the best of our knowledge this is the first study examining the issue of macroeconomic uncertainty and performance for Asian countries. The most closely related studies to ours focus on industrialized countries (Grier and Perry (2000), Grier et al. (2004), and Bredin and Fountas (2005)). These papers have concentrated on fully developed economies and adopt a variant of the GARCH model for varying samples and data frequencies. For example, Grier and Perry (2000) use monthly US data for 1948-1996. Out of the four hypotheses tested the authors find support only for the Friedman hypothesis. The present study differs in several respects from the above studies. First, our sample includes data on Asian countries. Second,

[9]In fact, in 2005, stock market capitalization as a percentage of GDP in Singapore and Malaysia exceeded that in the US, UK and Germany. The figure for South Korea was also quite large. Moreover, financial sector assets (stock, bonds and bank loans) as a share of GDP in Singapore exceeded those in the US whereas South Korean assets did not lag much behind the share of US assets. (World Bank Financial Structure Database).

we treat inflation and output growth uncertainty in a simultaneous framework that allows for asymmetric effects of uncertainty. Finally, unlike the papers discussed above, we investigate the dynamic inflation-growth relationship using impulse response functions.

6 Conclusions

We have applied a bivariate GARCH-M model that allows for asymmetries in five Asian countries to examine the effects of real and nominal uncertainty on inflation and output growth. Institutional and financial structure differences among these countries do exist, thus indicating potential variations in the effect of macroeconomic uncertainty on performance. Our econometric methodology is quite general as it nests other simpler GARCH models and allows us to test for four economic theories associated with the Friedman, Cukierman-Meltzer, Black, and Devereux hypotheses. Our simultaneous approach that proxies uncertainty by the conditional variance of unanticipated shocks to the time series of inflation and output growth leads to a number of important conclusions.

First, contrary to popular belief, Friedman's claim that inflation uncertainty can be detrimental to the economy's real sector receives very little support in our study. Second, we obtain mixed evidence in favour of the Cukierman-Meltzer hypothesis. Thus, as expected, countries are anticipated to react differently to a change in the degree of uncertainty surrounding the inflation rate. Third, we find that in most countries output growth uncertainty is a negative determinant of the growth rate, whereas in none of our countries the effect is positive. This result supports the recent emphasis in macroeconomic modelling on the simultaneous analysis of economic growth and business cycle variability. It also has implications for monetary policymaking. Central banks that place excessive emphasis on price stability and allow undue variability in growth may jeopardise the growth prospects of their economies. Finally, we find very little support for the positive contribution of output uncertainty to inflation, i.e., the Devereux hypothesis. Our results show that macroeconomic uncertainty in several cases may even improve macroeconomic performance, as it is associated with a higher average output growth rate and a lower inflation rate.

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Figure 1:

Impulse Response Functions for MGARCH-M VAR

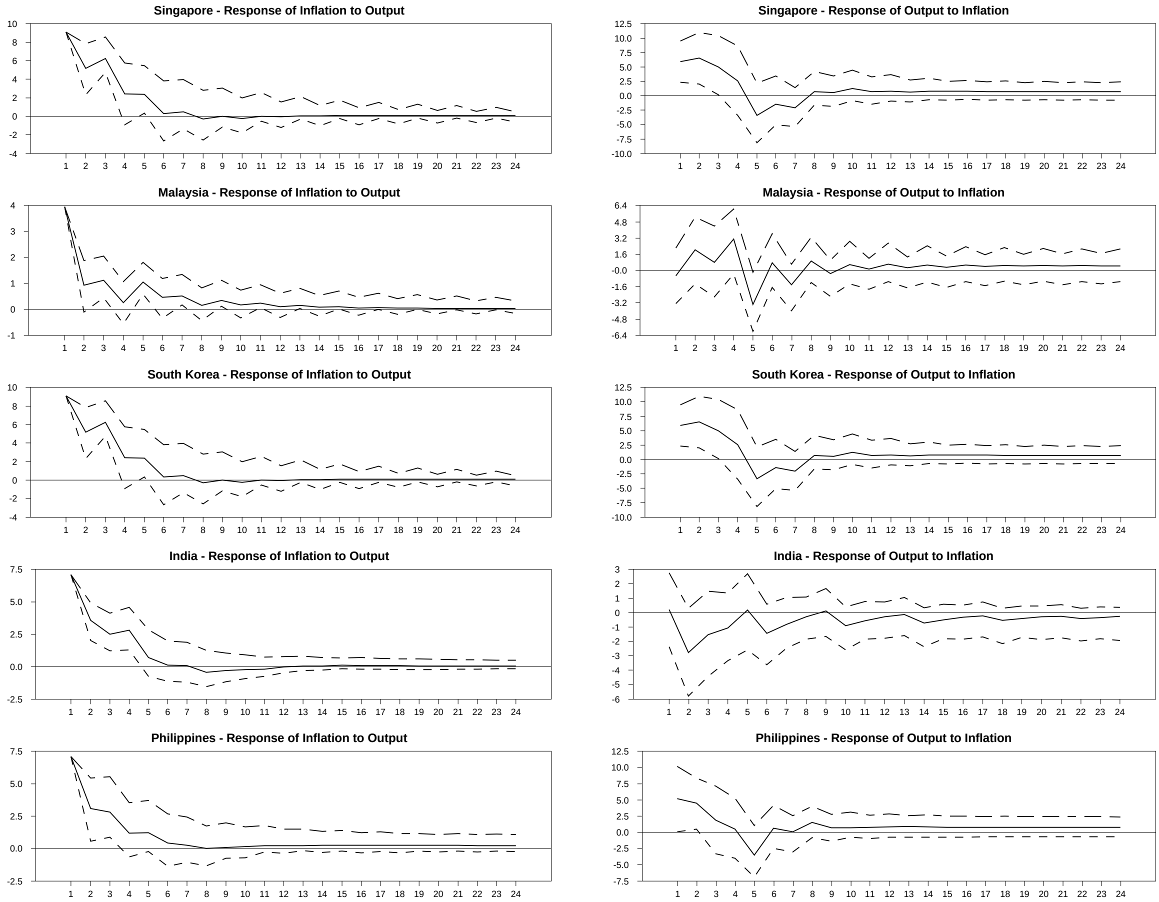

Table 1: Specification Tests

India	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.07]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
S. Korea	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Malaysia	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.01]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Philippines	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.01]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Singapore	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**

Note: The marginal significance levels are given in squared brackets.

Table 2: The Values of the Ψ Matrix

	Ψ_{11}	Ψ_{12}	Ψ_{21}	Ψ_{22}
India	-0.36	-0.64	0.63*	-0.69*
	(0.35)	(0.42)	(0.25)	(0.30)
S. Korea	-0.23*	0.81*	-0.19	0.55*
	(0.01)	(0.04)	(0.55)	(0.04)
Malaysia	-0.18	1.30	0.00	0.13
	(0.45)	(0.72)	(0.03)	(0.21)
Philippines	-0.55*	2.55*	-0.01	-0.12*
	(0.01)	(0.03)	(0.01)	(0.02)
Singapore	-0.84	1.98*	-0.17*	-0.17*
	(0.45)	(0.78)	(0.08)	(0.07)

Notes: The numbers in brackets are standard errors and the symbol * denotes significance at 5%. The coefficients Ψ_{11} and Ψ_{21} measure the effects of growth uncertainty on growth and inflation, respectively. The coefficients Ψ_{12} and Ψ_{22} measure the effect of inflation uncertainty on growth and inflation, respectively.

Table 3: The Values of the Ψ Matrix - VAR-GARCH-M

	Ψ_{11}	Ψ_{12}	Ψ_{21}	Ψ_{22}
India	-0.26	-0.91	0.15	-0.54
	(0.57)	(0.55)	(0.08)	(0.34)
S. Korea	-0.65*	2.08*	-0.04	0.12
	(0.15)	(0.50)	(0.08)	(0.39)
Malaysia	-0.11	0.20	0.00	0.23
	(0.11)	(0.74)	(0.01)	(0.22)
Philippines	-0.49*	0.37	-0.78	-0.53*
	(0.25)	(1.05)	(1.23)	(0.24)
Singapore	-0.54*	0.73*	-0.05	0.22
	(0.21)	(0.26)	(0.07)	(0.20)

Notes: The numbers in brackets are standard errors and the symbol * denotes significance at 5%. The coefficients Ψ_{11} and Ψ_{21} measure the effects of growth uncertainty on growth and inflation, respectively. The coefficients Ψ_{12} and Ψ_{22} measure the effect of inflation uncertainty on growth and inflation, respectively.