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Abstract

This article tests the Black's hypothesis in five crisis-affected Asian countries (India, Japan, Malaysia, South Korea, and Thailand). The hypothesis posits that economies face a positive relationship between output growth and output volatility. Using monthly data of the industrial production indices in the five economies and applying the ARCH/GARCH models to generate a measure of output volatility to conduct the two-step approach, the results show that output volatility positively Granger causes output growth in two economies, Japan, and South Korea. The results indicate that countries with specialized technology are compensated for associated risk. In addition, the impact of the 1997 Asian financial crisis is minimal such that it will not alter the volatility and growth relationship.

***Keywords*:** Output volatility, output growth, ARCH/GARCH model, causality
JEL Classification Codes*:* C22, C51, C52, E32

1. Introduction

Business cycle fluctuations and long-run economic growth have been recently integrated in recent empirical studies. Most studies have drawn conclusion from both individual country and cross-country data. However, the positive relationship between output volatility and output growth is still controversial. The notion raised by Mirman (1971) posits that higher economic uncertainty raises precautionary savings and leads to higher output growth. Black (1987) states that real uncertainty positively impacts growth. In other words, there is a positive tradeoff between output growth and output uncertainty. The argument is that technology comes with expected returns associated with degree of specialization and varying level of risk or uncertainty. Therefore, investment occurs in specialized technologies only if expected returns can sufficiently compensate for the associated risk. This is the so-called 'Black's Hypothesis.' This hypothesis is disproved by Bernanke (1983) and Pindyck (1991) who find that there exists a negative relationship between output volatility and output growth stemming from investment irreversibilities at firm level. Economic reasoning behind these two findings is that output volatility generates uncertainty about future demand that impedes investment and thus leads to a negative relationship. These are the notions of the effect of real (or output uncertainty) on growth that works through its impact on investment.

Empirical evidence that gives mixed results concerning the relationship between output volatility and output growth can be drawn from the results of various studies. Kormendi and MeGuire (1985) find that countries with higher output volatility enjoy higher mean growth rate while Zarnowitz and Moore (1986) find that the US growth rate tends to be lower during the period of high volatility.

Grier and Tullock (1989) include more countries in the sample and reveal the evidence that support the positive relation between growth and volatility. On the contrary, Ramsey and Ramsey (1995) report a negative relationship. Caporale and MacKiernan (1996) use post-war monthly UK industrial production data and report evidence of significantly positive tradeoff. Additionally, Caporale and MacKiernan (1998) employ an ARCH-M model applied to the annual US data on real GDP and find a significantly positive relationship between output growth and its volatility. Contrary to Coporale and MacKiernan's findings, Speight (1999) uses GARCH-in-mean (GARCH-M) models applied to post-war monthly UK industrial production data, but find no relationship between output variability and growth. Blackburn (1999) reports evidence showing that volatility raises the long-run economic growth. There is also a controversial issue concerning the asymmetric impact of output volatility on output growth. Hamori (2000) uses GARCH, TGARCH, and EGARCH models to examine the existence of asymmetry between volatility and growth in the United States, United Kingdom, and Japan. The results show non-existence of asymmetry, i.e., there is no evidence indicating more volatility during recession and less volatility during expansion. Henry and Olekalns (2002) use postwar US real GDP data and find that output volatility is highest when the US economy is contracting. Furthermore, economic expansion following a recession is offset by the negative impact of output volatility. Martin and Roger (2000) also find a negative relationship. Using a sample of 24 OECD countries, Kneller and Young (2001) find negative relationship. Fountas, Karanasos and Mendoza (2004) employ EGARCH model of Nelson (1991) to examine this relationship using quarterly data on Japanese GDP. They find that output variability does not affect output growth. In addition, asymmetric impact is not found. An overview by Rebello (2005) indicates that the evidence of the impact of real uncertainty on output growth is ambiguous. The general models of business cycles stipulate that output fluctuations are caused by monetary, fiscal, oil or technology shocks while the link between output fluctuations and growth is not considered in real business cycle models. Fountas and Karanasos (2006) find that higher output growth leads to lower output volatility. Beamont, Norrbin, and Yigit (2008) employ several GARCH in mean models to investigate the link between volatility and output growth in 20 OECD countries and find only little evidence of this link. Fang and Miller (2008) account for the possible effects of structural change in the volatility process. Their results show no significant relationship between output growth and its volatility in the US data during 1947-2006. Lee (2010) revises the empirical relationship between output growth and volatility using panel data of monthly industrial production indexes of G7 countries over the period 1965-2007, and finds evidence that supports the Black hypothesis.

The 1997 Asian financial crisis caused large currency devaluations in at least six Asian countries. Japan and South Korea suffered from bankruptcy of commercial banks and financial corporations while Thailand suffered from a huge devaluation of the Thai baht. Malaysia imposed measures to stabilize the Malaysian ringgit. The hardest hit countries are Malaysia, South Korea, and Thailand. The least-affected country is India.[1] The main objective of this paper is to test the Black's hypothesis in the five crisis-affect Asian economies, namely India, Japan, Malaysia, South Korea, and Thailand. The five countries are selected for the analysis for three reasons. First, these countries have complete and long-horizon data sets such that the measures of volatility will contain less measurement error. Second, they have different degrees of economic development. Japan is an industrialized country while South Korea is one of the four Asian tigers. For the remaining three countries, India, Malaysia, and Thailand rely heavily on industrial production, which has forward and backward linkages to other sectors in the economies. In addition, industrialization is an engine of growth in these countries. Therefore, it is reasonable to use changes in industrial production index as a proxy of output growth. Third, they are affected by the 1997 Asian financial crisis at different degrees. The results from the analysis should be able to shed light on how output growth measured by the rate of change in industrial production index is affected by the financial crisis. In testing the impact of the crisis on output growth process, the dummy variable that captures the impact of the Asian financial crisis is incorporated in the

[1] See the causes and effects, and policy actions after the crisis in Corden (2007).

ARCH/GARCH model. The results from this paper show that the impact of the Asian financial crisis is negligible. Furthermore, output volatility causes output growth to rise only in the case of Japan and South Korea. The next section presents the ARCH/GARCH models used in generating output volatility. Section 3 presents estimations and empirical results. Finally, Section 4 provides main conclusions.

2. The ARCH/GARCH Model

The autoregressive conditional heteroskedasticity (ARCH) model proposed by Engle (1982) takes into account of the high persistence of volatility and helps to forecast the conditional variance. To investigate the output growth and output volatility tradeoff, the AR(p)-ARCH(1) model is specified as

$$y_t = a_0 + \sum_{i=1}^{p} a_i y_{t-i} + \delta D + \varepsilon_t \tag{1}$$

and

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 \tag{2}$$

where y is the growth rate of output (proxied by the rate of change of industrial production index), which follows the autoregressive process of order p. The term ε^2_{t-1} is the ARCH term, and h_t is the conditional variance. Equation (1) is the mean equation while equation (2) is the variance equation. D is the financial crisis dummy variable, which takes the value of 1 from July 1997 onwards and zero otherwise.

Bollerslev (1986) generalizes the ARCH model called the GARCH(1,1) model by incorporating the past forecast variance term (h_{t-1}) in the conditional variance equation improves the ARCH model. The conditional variance equation of GARCH(1,1) model is

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \tag{3}$$

The ARCH term gives the condition on news about volatility from past period while the GARCH term is the past forecast variance. The conditional variance in the current period depends on a constant term, past information about volatility (the ARCH term), and past forecast variance (the GARCH term). This implies that an agent predicts the current period variance by forming a weighted average from past forecast. The restrictions of the model are as follows: (1) the coefficients in the conditional variance are non-negative, and (2) the sum of the coefficients of the ARCH and GARCH terms are less than one ($\alpha_1+\beta_1<1$), which indicates that the conditional variance series are stationary. The GARCH(1,1) model is widely used and approximates any arbitrary ARCH model, i.e., an insignificant estimated β_1 is an ARCH model.

There are alternative models of the conditional variance.[2] The exponential GARCH (EGARCH) model proposed by Nelson (1991) is an asymmetric or leverage volatility model. This model does not impose the non-negativity constraints on the parameters. The conditional variance equation of the EGARCH(1,1) model can be specified as

$$\log(h_t) = \alpha_0 + \alpha_1 \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right| + \alpha_2 \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \beta \log(h_{t-1}) \tag{4}$$

The error term in the mean equation is independently and normally distributed random variable with mean zero and variance of one. Equations (1) and (4) is an AR(p)-EGARCH(1,1) model.[3]

To examine the relationship between output growth and output volatility, one can employ two approaches: ARCH/GARCH-in-mean (ARCH/GARCH-M) model. The ARCH-M model proposed by

[2] See details of these models in Grier and Perry (1998) who study the relationship between inflation and inflation uncertainty in the G7 countries.

[3] Fountas, Ioannidis, and Karanasos (2004) apply this model to investigate the relationship between inflation and inflation uncertainty in six European Union countries.

Engle, Lilien, and Robins (1987) incorporates the conditional variance in the mean equation. Even though the ARCH/GARCH-M model can be useful in testing the link between output growth and output volatility, the main drawback of the model is that it does not allow the lagged independent variable to affect the dependent variable. Therefore the two-step approach may be superior to be used to examine the relationship between output growth and its volatility (see for example Grier and Perry (1998) who directly examine the relationship between inflation and inflation uncertainty).

In the two-step approach, the first step is to estimate the conditional variance series as a measure of output volatility (or uncertainty) from ARCH/GARCH and EGARCH models specified above. The second step is to perform bivariate Granger causality test which is specified as

$$y_t = b_0 + \sum_{i=1}^{k} b_i y_{t-i} + \sum_{i=1}^{k} c_i h_{t-i} + u_{1t} \tag{5}$$

and

$$h_t = d_0 + \sum_{i=1}^{k} d_i y_{t-i} + \sum_{i=1}^{k} e_i h_{t-i} + u_{2t} \tag{6}$$

Equation (5) is used to test the causation running from output volatility to output growth, and equation (6) is used to test the causation running from output growth to output volatility. For the EGARCH model, h_t is replaced by $\log(h_t)$.

3. Estimation and Results

3.1. Data

The time series data on the industrial production index (IPI) of India, Japan, Malaysia, South Korea, and Thailand are used as a proxy of real output. The sample period covers January 1987 to December 2008 for the Thailand, and January 1981 to December 2009 for the remaining four countries. The data for Thailand are obtained from the Bank of Thailand statistics while the data for the remaining four countries are obtained from *IMF* Interntional Financial Statistics. The series are seasonally adjusted by the author. Real output growth (y_t) is defined as the first difference in the log of IPI, which is $y_t = \log(IPI_t/IPI_{t-1})$. Summary statistics of the output growth series are reported in Table 1.

Table 1: Summary statistics of the output growth series

Country	Mean	Standard Deviation	Skewness	Kurtosis	Jarque-Bera
India	0.006	0.032	0.150	13.697	1,656.031 (0.000)
Japan	0.001	0.027	-0.307	4.432	35.110 (0.000)
Malaysia	0.006	0.053	1.050	10.364	847.743 (0.000)
South Korea	0.007	0.040	-0.197	4.372	29.466 (0.000)
Thailand	0.006	0.039	-0.452	4.521	34.292 (0.000)

Note: The number in parenthesis is the probability of accepting the null hypothesis of normal distribution.

The average monthly growth rate of Korea is the highest while that of Japan is the lowest. Malaysia has the highest standard deviation of growth rate, and Japan has the lowest standard deviation. The skewness measure indicates positively skewed for India and Malaysia and negatively skewed for Japan, South Korea and Thailand. The kurtosis measure shows that the output growth rates of India and Malaysia are highly leptokurtic. However, the Jarque-Bera normality test rejects the null hypothesis of a normal distribution of the growth rate in all cases.

3.2. Unit root tests

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are used to test for the stationary properties of the output growth data. The results in Table 4 reveal that all series are stationary. Therefore, the output volatility can be estimated within the AR(p)-GARCH framework.

Table 2: Unit root tests of the output growth series

Country	ADF (constant)	ADF (constant and linear trend)	PP (constrant)	PP (constant and linear trend)
India	-5.007 [12] (0.000)***	-5.075 [12] (0.000)***	-46.373 [4] (0.000)***	-46.336 [4] (0.000)***
Japan	-5.446 [16] (0.000)***	-5.740 [16] (0.000)***	-23.244 [1] (0.000)***	-23.048 [2] (0.000)***
Malaysia	-29.984 [0] (0.000)	-30.031 [0] (0.000)***	-29.629 [3] (0.000)***	-29.813 [4] (0.000)***
South Korea	-28.414 [0] (0.000)***	-28.460 [0] (0.000)***	-29.994 [9] (0.000)***	-30.753 [0] (0.000)***
Thailand	-2.996 [11] (0.037)**	-3.197 [11] (0.037)*	-19.940 [10] (0.037)***	-20.098 [11] (0.037)***

***Notes*:** ADF is the augmented Dickey-Fuller test statistic, and PP is the Phillips-Perron test statistic. The number in bracket is the optimal lag length for ADF test determined by AIC and the optimal bandwidth for PP test determined by Bartlett kernel. The number in parenthesis is the probability of accepting the null hypothesis of unit root. ***, **, and * denote significance at the 1, 5, and 10 percent respectively.

It should also be noted that all output growth series are stationary in the presence of the 1997 Asian financial crisis.

3.3. Results

3.3.1. ARCH/GARCH model Estimates

The parameter estimates from AR(p)-ARCH/GARCH models for the five countries are reported in Table 3. The AR(p)-ARCH(1)-M model is suitable for India and Thailand with the order of the AR(8)- and AR(6)-GARCH(1,1) processes. For Japan, Malaysia and South Korea, the AR(p)-GARCH(1,1) model is suitable with the AR(3), AR(1) and AR(1) processes respectively.[4]

The AR(p)-ARCH(1)/GARCH(1,1) models are estimated and the conditional variances from each estimated model are used as measures of output volatility or uncertainty for all countries. The parameter estimates of ARCH(1)/GARCH(1,1) model are shown in Table 3.

Table 3: Results from AR(p)-ARCH/GARCH(1,1) model

Parameter	India	Japan	Malaysia	South Korea	Thailand
Δ	-0.003	-0.002	-0.007	-0.001	-0.002
α_0	0.001***	0.001***	0.001***	0.001	0.001***
α_1	0.358***	0.152***	0.226***	0.099***	0.335***
β_1		0.519***	0.688***	0.587***	
Log-likelihood	765.866	799.391	589.690	663.901	498.548
Q(4)/p-value	3.203 (0.524)	1.382 (0.847)	2.536 (0.638)	2.124 (0.713)	2.735 (0.600)
Q(8)/p-value	4.679 (0.791)	10.366 (0.240)	2.940 (0.938)	9.336 (0.315)	5.669 (0.684)
$Q^2(4)$/p-value	5.786 (0.216)	9.128 (0.058)	1.588 (0.811)	1.588 (0.783)	0.927 (0.921)
$Q^2(8)$/p-value	8.745 (0.364)	12.116 (0.146)	3.988 (0.858)	7.606 (0.473)	3.956 (0.861)

***Note*:** ***denotes significance at the 1 percent.

For all estimated equations, the ARCH/GARCH parameters (α_1 and β_1) are significantly different from zero. The results reported in Table 3 pass all diagnostic tests. The null hypothesis of uncorrelated standardized residuals is well supported by the Ljung-Box Q-statistic while the null hypothesis of uncorrelated squared standardized residuals is supported by the Ljung-Box Q_2 statistic. The rejection of the null hypothesis indicates that there is evidence of suitable model specification. The sum of the coefficients of ARCH and GARCH terms (α_1 and β_1) are less than one for Japan, Malaysia, and South Korea, which indicates the stationarity of the conditional variance series. Furthermore, the

[4] The order of lags in the AR(p) process is determined by the Schwarz Information Criterion (SIC).

coefficient α1 for India and Thailand is less than one, which indicates that the conditional variance series is stationary. The negative impact of the 1997 financial crisis is insignificant in all cases, which can be witnessed by the p-value of the estimated coefficient δ. The output volatility is generated for each country to perform Granger causality tests.

The estimated results for AR(p)-EGARCH(1,1) model are reported in Table 4. The negative impact of the 1997 financial crisis is observed in India and Malaysia, but with the significance level of 10 percent only. In addition, the size of the impact of the financial crisis is minimal. Again, the estimated model passes diagnostic tests in all countries. The GARCH variance series are generated as a measure of output volatility or real uncertainty.

Table 4: Results from AR(p)-EGARCH(1,1)-M model

Parameter	India	Japan	Malaysia	South Korea	Thailand
Δ	-0.004*	-0.001	-0.007*	-1.004	-0.001
α_0	-5.008***	-0.892**	-2.829***	0.147*	-4.855**
α_1	0.656***	0.117*	0.543***	0.057	0.494***
α_2	0.013	-0.185***	-0.179*	-0.054	-1.111
Β	0.385**	0.893***	0.616***	0.867**	0.333***
Log-likelihood	778.666	806.542	602.927	669.879	499.435
Q(4)/p-value	3.455 (0.485)	1.441 (0.837)	4.315 (0.365)	1.926 (0.749)	4.487 (0.344)
Q(8)/p-value	6.026 (0.644)	12.130 (0.146)	5.140 (0.742)	9.335 (0.315)	7.947 (0.439)
$Q^2(4)$/p-value	7.435 (0.115)	8.905 (0.064)	0.571 (0.989)	2.459 (0.652)	1.344 (0.854)
$Q^2(8)$/p-value	9.704 (0.286)	11.062 (0.198)	6.448 (0.597)	6.848 (0.553)	3.464 (0.922)

Note: ***, **, and * denote significance at the 1, 5, and 10 percent respectively.

3.3.2. Granger Causality Test Results

Granger causality tests are performed using the estimated conditional volatility series from the AR(p)-ARCH(1)/GARCH(1,1) model in Table 3 and the output growth series. Table 5 reports the results of causality tests.

Table 5: Results of Granger causality tests

Country	H_0: Output volatility does not cause output growth	H_0: Output growth does not cause output volatility	Optimal lag
India	7.792 (-) (0.000)***	5.432 (+) (0.000)***	8
Japan	2.267 (+) (0.007)***	10.951 (+) (0.007)***	6
Malaysia	0.551 (-) (0.577)	14.377 (+) (0.000)***	2
South Korea	4.277 (+) (0.015)**	9.316 (+) (0.000)***	2
Thailand	0.281 (-) (0.597)	9.414 (+) (0.002)***	1

Notes: The number in parenthesis is the probability of accepting the null hypothesis of no causality. The optimal lags are determined by AIC.

The results in Table 5 show that bidirectional causality exists in the cases of India, Japan, and South Korea while unidirectional causality exists in the cases of Malaysia and Thailand. In all countries, the causation running from output growth to its volatility. In other words, output growth raises output uncertainty. The positive sign in parenthesis indicates the positive relationship while the negative sign indicates the negative one. The Black's hypothesis holds in Japan and South Korea only. For the other three countries, output volatility lower output growth but the impact is insignificant.

Using the conditional volatility generated from the AR(p)-EGARCH(1,1) and output growth series, the results of Granger causality tests are reported in Table 6.

Table 6: Results of Granger causality tests

Country	H_0: Output volatility does not cause output growth	H_0: Output growth does not cause output volatility	Optimal lag
India	5.416 (-) (0.000)***	5.455 (+) (0.000)***	4
Japan	7.171 (+) (0.000)***	84.033 (+) (0.000)***	6
Malaysia	0.018 (-) (0.894)	19.532 (+) (0.000)***	1
South Korea	2.701 (+) (0.069)*	103.662 (+) (0.000)***	2
Thailand	2.249 (-) (0.025)**	9.681 (+) (0.000)***	8

***Notes*:** The number in parenthesis is the probability of accepting the null hypothesis of no causality. The optimal lags are determined by AIC.

The results are the same as those of Table 5 and convince that the Black's hypothesis holds for Japan and South Korea. Output volatility is negatively related to output growth in India and Thailand.

It should be noted that the test results using volatility from both ARCH/GARCH and EGARCH model along with the Granger causality test give the evidence that output uncertainty is positively related to output growth in the advanced country, Japan, and the high-technology newly-industrialized country, South Korea.

4. Conclusions

This paper examines the relationship between output growth and its volatility in five crisis-affected Asian economies, namely India, Japan, Malaysia, South Korea, and Thailand. Grier and Perry (1998) point out that Granger causality test can suffer from the generated volatility series, but the GARCH in mean model is the simultaneous approach that does not capture the lagged casual effects of the conditional variances on the conditional means. Granger causality test also minimizes the number of estimated parameters. The more serious problem in using the simultaneous approach (or GARCH-M) is that incorporating lagged output growth in the conditional variance equations may lead to the negativity of the conditional variances. The present study adopts the two-stage procedure to directly test the Black's hypothesis in five crisis-affect Asian economies. The AR(p)-ARCH(1)/GARCH(1,1) and EGARCH(1,1) models are estimated so as to generate the output volatility series and the standard causality test is used to investigate causal relationship between output volatility and output growth.

The results show that the impact of financial crisis is minimal and not significant in most countries, which is consistent with the belief of mainstream economists. Furthermore, the asymmetric effects of output volatility on output growth are not observed in Japan and Malaysia. The two-step procedure that allows for causal effects of output volatility and output growth may be superior to the ARCH/GARCH in mean model that does not allow for lagged independent variable to affect dependent variable. Based upon the results of bivariate Granger causality test, the countries that use high technology are sufficiently compensated for the associated risk stemming from specialized technology as can be seen in Japan and South Korea. The results from the two-step are consistent and reliable in examining the relationship between output growth and output uncertainty.

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