行政院國家科學委員會專題研究計畫 成果報告

經濟成長與其波動性和物價膨脹與其不確定性之互動關係研究

研究成果報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 97-2410-H-032-003-
執 行 期 間 ：97 年 08 月 01 日至 98 年 07 月 31 日
執 行 單 位 ：淡江大學經濟學系

計 畫 主 持 人：林淑琴
共 同 主 持 人：金東炫
計畫參與人員：碩士級-專任助理人員：秦國軒
學士級-專任助理人員：楊重洲

報 告 附 件 ：出席國際會議研究心得報告及發表論文

處 理 方 式 ：本計畫可公開查詢

中 華 民 國 98 年 08 月 24 日

Economic Growth and Growth Volatility Revisited

Abstract

This paper investigates the relationship between economic growth and growth volatility through simultaneous equations system. By employing the identification through Heteroskedasticity method of Rigobon (2003) and using a panel of 158 countries over the period of 1960-2007, we find that output volatility is detrimental to economic growth, suggesting that stabilization policies to mitigate short-run economic fluctuations contribute to long-run economic growth. We also find that economic growth accelerates output variability, supporting the feedback effects from growth to the volatility. The evidence is robust to a number of sensitivity tests. In addition, when splitting the data into different subsamples according to the attributes of countries, we find that while the growth effect on volatility varies, a negative impact of volatility on growth continues to hold.

Keywords: Economic Growth, Growth Volatility, Simultaneous equations model, Identification through heteroskedasticity

JEL Classification: C33, N10, O50

1. Introduction

Recently, much attention has been directed to the issue of whether macroeconomic volatility affects economic performance, particularly to the relationship between economic growth and growth volatility.[1] Traditionally, business cycle and economic growth models are treated as different doctrines in the sense that short-run economic fluctuations and long-run economic growth are determined independently in different time horizons. However, since the influential work of Ramey and Ramey (1995) that finds a significant effect of growth volatility on economic growth, considerable and growing effort has been devoted to the link between these two variables. The evidence of significant effects of growth volatility has important policy implications for the determination of economic growth. It provides a channel through which short-term government policies may influence long-term output growth. If, for example, growth volatility is found to affect economic growth positively, short-run stabilization may be detrimental to long-run growth such that the government confronts tradeoffs between short-term stability and long-run economic growth. If, instead, growth volatility tends to influence growth negatively, stabilization policies may improve economic growth.

However, the theoretical literature on the relationship between economic growth and growth volatility is still far from being uncontroversial. The literature on irreversible investment and the option value of waiting predicts a negative relationship between growth uncertainty and average growth. In these models, an increase in uncertainty about future profit raises the value of waiting, thus delaying investment and lowering growth (e.g., Pindyck, 1991; Ramey and Ramey, 1991). In contrast, there is an argument attributable to Black (1987) that implies a positive relationship. This is based on the assumptions that technology choices are made from a menu of possibilities where the average rate of return (growth) and return volatility (growth volatility) are positively correlated, and that technology which produces faster average growth is inherently riskier. Another argument in favor of a positive relationship between growth and volatility comes from the theory of precautionary savings where increased risk raises desired saving and hence investment and growth (Mirman, 1971). Furthermore, proponents of endogenous growth theory assert that the relationship between growth and volatility depends on whether productivity-improving activity and production are substitutes or complements.[2]

This conflict in theoretical predictions is reflected in the empirical literature. In

[1] The growing literature also emphasizes potential impacts of volatility on inequality and investment. Growth volatility is said to strengthen the gap between the rich and the poor, as the poor may lack the liquid wealth or access to credit that would be needed to smooth consumption. And the uncertainty associated with short-run output variations can translate into lower investment (Aizenman and Marion, 1999)

[2] See Blackburn (1999), Martin and Rogers (2000), and Blackburn and Pelloni (2005) for discussions.

cross-section studies, Kormendi and Meguire (1985) and Grier and Tullock (1989) are among the earliest studies to directly examine the growth-volatility relationship and report a positive relationship. However, Ramey and Ramey (1995) find that growth and volatility are negatively related. Subsequent studies such as Martin and Rogers (2000), Fatas (2002), Hnatkovska and Loayza (2005), Rafferty (2005), and Aghion, Banerjee, Angeletos, and Manova (2005) also find similar results.[3] Studies based on time series data also reach mixed, if not contradictory, conclusions, depending on the time period, the frequency, and the countries considered (though most studies are concentrated on industrialized countries). For example, using US data, Caporale and McKieman (1998), Grier and Perry (2000), and Grier, Henry, Olekalns, and Shields (2004) obtain evidence for positive effect of output uncertainty on growth, while Henry and Olekalns (2002) support the negative effect. Speight (1999) and Fountas, Karanasos and Kim (2002) finds no significant growth effects in the UK and Japan, respectively. Others including Fountas and Karanasos (2006) and Fountas, Karanasos and Kim (2006) find mixed results from the G3 and G7 countries, respectively. In a sample of Asian Countries, Bredin, Elder and Fountas (2009) find that uncertainty regarding the output growth rate is related negatively to the average growth rate.

One of the main criticisms on existing empirical works is that growth and volatility are endogenously and jointly determined. For example, if an increase in output growth leads to more inflation, and if inflation causes a rise in inflation uncertainty, then a higher growth may lead a lower growth uncertainty, given that inflation uncertainty and growth uncertainty are substitute. However, if the monetary authorities respond inflation pressure by monetary contraction which reduces both inflation and inflation uncertainty, then output growth increases growth volatility. Alternatively, as important determinants of economic growth, a large literature points to domestic policy management (such as inflation, openness and fiscal deficits),[4] the role of financial systems (such as banking and stock market development),[5] and more general institutional attributes (such as legal origins, settler mortality and property rights) and geographic characteristics (such as natural resource endowments, market access and climate variability).[6] These factors are also attributed to cross-country

[3] There is emerging research presenting disaggregated evidence. Imbs (2007) shows that volatility promotes growth at the firm level. By contrast, Chong and Gradstein (2009) find that volatility is detrimental to firm growth, and such an adverse effect is magnified by institutional obstacles.

[4] See Gillman (2005) for theoretical discussions, and Barro (1995), Bullard and Keating (1995), Bruno and Easterly (1998), Khan and Senhadji (2001), and Bose and Murshid (2008), among others, for empirical investigations on the link between growth and inflation.

[5] See Levine (1997, 2005) for detailed discussions and references therein.

[6] See Knack and Keefer (1995), Hall and Jones (1999), Acemoglu, Robinson and Johnson (2001), Acemoglu and Johnson (2005), Easterly and Levine (2003), Rodrik, Subramanian and Trebbi (2004), and Bhattacharyya (2009), to name a few.

differences in growth volatility.[7] Therefore, the finding of a positive or negative link between growth and volatility may simply reflect a reverse causation from volatility to growth or a common driving forces rather than a causal relationship. [8]

In this respect, this paper intends to make a contribution to the literature by providing empirical relevance to the growth-volatility correlation through a simultaneous equations model (SEM) in which the endogenous and joint determination of the two variables can be adequately addressed. And it considers the dynamics of stabilization policy in the phase of economic development. As it is known, however, an unrestricted SEM is underidentified so that structural parameters cannot be recovered into nontrivial solutions from reduced-form estimates. The problem of identification must be solved before estimation.

For this issue, it is conventional to impose *a priori* exclusion, sign, long-run, or covariance restrictions. As the empirical literature on the growth-volatility nexus implies, however, the exclusion, sign, and long-run restrictions are not suitable to this study. The sign and magnitude of the contemporaneous coefficients are main empirical matters. And near identification by covariance restriction does not apply to this case with sample heteroskedasticity. Another useful way is the instrumental variable approach. The method amounts to find valid instruments that are uncorrelated with the error term but correlated with the endogenous explanatory variable. However, it is difficult to come up with valid instruments for cross-country studies. And as shown in Bound, Jaeger and Baker (1995), weak instruments can lead to large inconsistency in parameter estimates even if the instruments are only weakly correlated with errors in structural equation.

Since the standard identification methodologies are not useful to this study, we rely on an alternative method called 'identification through heteroskedasticity (IH henceforth)' of Rigobon (2003),[9] to examine the coevolution between economic

[7] See Malik and Temple (2008) for detailed discussions and references therein.

[8] Related literature postulates that economic development will mitigate growth volatility. It is argued that less-developed countries are more volatile because of their relatively unsophisticated financial markets. For example, Acemoglu and Zilibotti (1997) argue that weakly developed economies lack significant diversification. The absence of opportunities for diversification prevents agents from spreading risk as a hedge against shocks. Aghion, Banerjee, and Piketty (1999) establish a related theoretical link between low financial sector development and high volatility. Their model shows that a sharper separation between savers and investors results in greater volatility. One characteristic of a lesser-developed economy may be the lack of the skills and connections needed for someone to partake in successful investment opportunities, thus preventing them from hedging against shocks. However, as economies develop, incomes, investment, and education levels should increase. This will lead to an increase in financial deepening, industry diversification, and more savvy savers who exploit more diversified investment opportunities. Consequently, one would expect that as the level of economic development increases, the level of GDP growth volatility will decrease. Edwards and Thames (2009) provide empirical evidence of this sort.

[9] Since its introduction with an analysis of the contemporaneous relationship between returns on Argentinean, Brazilian, and Mexican sovereign bonds (Rigobon, 2003), the IH approach has been employed to estimate the reaction of monetary policy to the stock market (Rigobon and Sack, 2003;

growth and growth volatility across countries and over time. The IH approach exploits the difference (heteroskedasticity) in the structural variances of subsamples to gain identification. Since sample heteroskedasticity is observed in both economic growth and the volatility, the IH method solves the identification problem with an assumption of coefficient stability,[10] as proposed and proved by Rigobon (2003).

Our empirical results based on a large dataset including 158 countries over 1960-2007 show that after accounting for the feedback effect of growth on volatility, heightened growth volatility would hinder economic growth. We also find that faster economic growth would result in more volatile output growth. The evidence is robust to alternative sets of conditioning variables, econometric methods, and time periods. However, when splitting the data into country subsamples according to the level of income, financial development, trade openness, and inflation, we find that while the growth effect on volatility varies, a negative impact of volatility on growth continues to hold. Overall, the data highlight a negative effect of volatility on growth and indicate the need for stabilization policies to smooth volatility and promote output growth.

Our study is related to the literature on policy volatility and economic growth. Acemoglu *et al.* (2003) and Easterly (2005) argue that macroeconomic policy has an explanatory power for the cross-country variation in growth rates and per capita income only because they serve as a proxy for institutions. And, Fatas and Mihov (2006) posit that a key policy characteristic that matters for the long-term country performance is the volatility and present evidence in support of that policy volatility exerts a strong and direct negative impact on growth. Similar results are also found in Aizenman and Marion (1993) and Hopenhayn and Muniagurria (1996).

The remainder of the paper is organized as follows. Section 2 illustrates the identification problem, introduces the IH approach, and describes the data. Section 3 analyzes empirical results. And Section 4 concludes the paper.

2 Econometric Methodology and Data

2.1 Identification through Heteroskedasticity

A simultaneous equations model (SEM) describing the interrelationship between economic growth (g) and growth volatility (vol) is formed as

$$\begin{aligned} g &= \beta_1 vol + \varepsilon_1 \\ vol &= \beta_2 g + \varepsilon_2 \end{aligned} \qquad (1)$$

Bohl, Siklos and Werner, 2007), to examine the effect of openness on growth (Lee, Ricci and Rigobon, 2004), to investigate the interrelationships among economic institutions, political institutions, openness, and income level (Rigobon and Rodrik, 2005), to assess the relationship between exchange rates and interest rates (Caporale, Cipollini, and Demetriades, 2005), and so on.

[10] As discussed in Rigobon (2003), this assumption is implicit in many econometric methodologies.

where $\varepsilon_i \sim \left(0, \sigma_i^2\right)$, i = 1 and 2, are the structural shocks to the 'growth' and 'volatility' regressions, and assumed to be contemporaneously and serially uncorrelated. In matrix form, model (1) is rewritten as

$$\begin{bmatrix} 1 & -\beta_1 \\ -\beta_2 & 1 \end{bmatrix} \begin{bmatrix} g \\ vol \end{bmatrix} = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix}$$

or

$$BY = \varepsilon \tag{2}$$

where the coefficient matrix B measures the contemporaneous relationship among the endogenous variables in the vector Y. Since the error term $\varepsilon = (\varepsilon_1, \varepsilon_2)'$ is assumed to be uncorrelated, the covariance matrix is

$$V(\varepsilon) = \Sigma = \begin{bmatrix} \sigma_1^2 & 0 \\ 0 & \sigma_2^2 \end{bmatrix} \tag{3}$$

Then, the reduced form is

$$Y = B^{-1}\varepsilon \tag{4}$$

with the reduced-form residual η given as

$$\eta = B^{-1}\varepsilon \tag{5}$$

The covariance matrix of the reduced-form innovations is

$$V(\eta) = B^{-1}\Sigma B^{-1'} = \Omega \tag{6}$$

As it is well known, the reduced-form equations in (4) can be consistently estimated by OLS, while the structural regressions in (2) cannot be.

The problem of identification concerns if the structural parameters can be recovered from the reduced-form estimates. It is generally impossible because the unrestricted SEM is underidentified.[11] There are solutions for the problem of identification such as imposition of restrictions on structural parameters and the instrumental variable approach. However, the standard methodologies are often inapplicable to applied economic studies. As an alternative, Rigobon (2003) suggests appealing to heteroskedasticity in the structural shocks to obtain identification of the simultaneous system. The idea of the IH approach is to increase the number of moment conditions so that the order and rank conditions can be satisfied. Assuming there are two regimes with different relative variance of the structural shocks, there are two reduced-form covariance matrices as

[11] There are 4 unknowns to be estimated: 2 structural parameters in B and 2 unknown variances of the structural shocks in Σ. However, the estimated covariance matrix of the reduced-form residuals, $\hat{\Omega}$, provides only $2(2+1)/2 = 3$ moment conditions. The standard identification problem arises since there are fewer equations (moments) than the number of unknowns.

$$\hat{\Omega}_1 = B^{-1}\Sigma_1 {B^{-1}}'$$
$$\hat{\Omega}_2 = B^{-1}\Sigma_2 {B^{-1}}'$$

Or specifically,

$$\begin{bmatrix} \omega_{g,1}^2 & \omega_{gvol,1} \\ \cdot & \omega_{vol,1}^2 \end{bmatrix} = \begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \sigma_{g,1}^2 & 0 \\ 0 & \sigma_{vol,1}^2 \end{bmatrix} {\begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1}}'$$
$$\begin{bmatrix} \omega_{g,2}^2 & \omega_{gvol,2} \\ \cdot & \omega_{vol,2}^2 \end{bmatrix} = \begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \sigma_{g,2}^2 & 0 \\ 0 & \sigma_{vol,2}^2 \end{bmatrix} {\begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1}}'$$

Hence there are 6 moment conditions equating $\omega_{g,1}^2$, $\omega_{gvol,1}$, $\omega_{vol,1}^2$, $\omega_{g,2}^2$, $\omega_{gvol,2}$, and $\omega_{vol,2}^2$ to their right-hand side counterparts. Then the 6 moments can be used to estimate the 2 structural parameters (β_1 and β_2) and the 4 variances of the structural shocks in two subsamples ($\sigma_{g,1}^2$, $\sigma_{vol,1}^2$, $\sigma_{g,2}^2$, and $\sigma_{vol,2}^2$). Moreover, Rigobon (2003) proves thoroughly that the IH method solves the problem of identification for the cases with more than two regimes, with common shocks, and even with misspecified heteroskedasticity.

With relevant explanatory variables added, the SEM of the growth-volatility nexus is

$$g = \beta_1 vol + x'\alpha_1 + \varepsilon_1$$
$$vol = \beta_2 g + x'\alpha_2 + \varepsilon_2$$

or

$$BY = \Gamma x + \varepsilon \qquad (7)$$

where x is a vector of relevant explanatory (control) variables common in both equations, and

$$\Gamma = \begin{bmatrix} \gamma_1' & 0 \\ 0 & \gamma_2' \end{bmatrix}$$

The reduced form is

$$Y = B^{-1}\Gamma x + \eta \qquad (8)$$

The consistent estimates of $\eta = B^{-1}\varepsilon$ and $B^{-1}\Gamma$ can be obtained by OLS (or the fixed-effect approach when panel data are used). The reduced-form residuals share the same properties as the endogenous variables. Thus Rigobon (2003) suggests computing covariance matrices in two subsamples defined by heteroskedasticity in the structural shocks and using these matrices in the GMM estimation of the contemporaneous coefficients.

2.2 Data Description

The dataset used in this study is taken from the World Development Indicators of World Bank (2008) and consists of 158 countries over the 1960-2007 period. Following common practice, the data are averaged over non-overlapping subperiods: 1960-1965, 1966-1970, 1971-1975, … , 2001-2007.[12] This gives up to 9 cross-sections per country. And we also use data covering the 1980-2007 period which is characterized as relatively moderate economic fluctuations, to check whether the relationship between growth and volatility differs with time periods considered. Economic growth (*growth*) is measured as the average growth rate of real GDP per capita over the non-overlapping subperiods.

Growth volatility (*volatility*) is measured by the standard deviation of annual growth rates of real GDP per capita over the subperiods. Conventionally, the volatility in the cross-section or time-series studies is measured by the (moving) standard deviation of a variable. However, the limitation of this measure lies in its inability to distinguish between variability and uncertainty. It includes the variance of both expected and unexpected components of a variable, even though the former does not imply any uncertainty. Since introduction of the ARCH approach, the prevalent measure of uncertainty has been the conditional standard deviation and variance. Specifically, GARCH-type techniques estimate a model of the variance of unpredictable innovations in a process. As argued, such a time-varying residual standard deviation or variance is better to capture uncertainty. Although uncertainty is usually of primary interest, there are at least two good reasons for focusing on volatility rather than uncertainty, as pointed by Malik and Temple (2008). First, some costs of output variation will be incurred even if the variation is anticipated, especially when the possibility of consumption smoothing and other behavioral responses is limited by market incompleteness and credit constraints. Second, the measurement of uncertainty relies on a specific forecasting model, usually a simple autoregressive model. Moreover, given that annual growth rates are not strongly autocorrelated, the two approaches are unlikely to differ greatly. As a robustness check, we also use the conditional standard deviations (*uncertainty*) derived from a GARCH model to proxy for growth uncertainty.

To further strengthen our results, we include alternative conditioning information sets. First, the simple conditioning set includes the initial GDP per capita (*igdp*) to capture (conditional) convergence, the investment to GDP ratio (*inv*), and the rate of

[12] The use of averages rather than annual data is to abstract from business cycles and to focus on the long-run link between growth and volatility. Averaging is also likely to lessen the impact of measurement errors and simplifies the specification of dynamics of the model.

population growth (*popg*) as a proxy for the rate of labor growth. Second, the policy conditioning set includes the simple set plus the ratio of government consumption to GDP (*gov*) as well as inflation rate (*inf*) to control for macroeconomic instability. Third, the full conditioning set further adds an openness index (*trade*) defined as the ratio of trade volume over GDP and financial development (*privo*) measured by bank credits to the private sector as a share of GDP. In addition, each conditioning set includes period dummies to control for time-varying factors and country-specific dummies to capture the effect of structural variables which do not change (significantly) over time. All control variables are in natural logarithm except for population growth and dummies. The list of sample countries and descriptive statistic summary are provided in Tables A1 and A2 in Appendix, respectively.

3 Empirical Results

3.1 Main Results

For identification of simultaneous-equation models, this paper employs the IH methodology. Applying the procedure suggested in Rigobon (2003), we first run the reduced-form *growth* and *volatility* regressions in (4) using the fixed-effect panel data approach and store the residuals.[13] The residuals share the same contemporaneous properties as the structural variables. We then compute the unconditional covariance matrix for each country and split the data into four distinct groups: high-low standard deviation groups of economic growth and the volatility. Following Lee, Ricci and Rigobon (2004), countries are grouped according to the median values. Finally, the covariance matrices are used to estimate the contemporaneous parameters through GMM.

The IH fixed-effect estimation results for the 1960-2007 period are summarized in Table 1. The overall message across alternative volatility measures and conditioning sets is that countries with higher volatility tend to experience lower economic growth, while countries with faster economic growth appear to confront greater volatility. For comparison, the results using OLS fixed- and random-effect techniques are reported in Tables A3 and A4 of Appendix.

First, when growth volatility is measured by the realized standard deviations as shown in Panel A of Table 1, volatility enters the growth equation negatively and highly significantly, implying that volatility is detrimental to growth. The negative growth effect of volatility is economically significant as well. A one-standard deviation increase in growth volatility is associated with a decline in output growth in

[13] The validity of IH methodology relies on heteroskedasticity in the structural variances. To avoid the heteroskedasticity arising from model specifications or omitted variables bias, we employ the estimator of panel fixed effect to control for time-invariant and other country-specific unobserved effects to minimize the possibility.

the range of 0.68-0.33 percent, depending upon the coefficient estimate used. By contrast, growth enters the volatility equation in a positive and significant way, implying that economic growth produces more volatility in output growth. However, the effect of growth on volatility turns out economically small. A one percent increase in output growth would cause output volatility to boost only by 0.06-0.01 standard deviation. The finding of coexistence of negative growth effect of volatility and positive volatility effect of growth appears insensitive to alternative model specifications.

Next, regarding the correlation between growth and uncertainty, an unexpected component of volatility, Panel B of Table 1 shows quite similar results. Across alternative conditioning sets, growth uncertainty has a highly significant and negative impact on output growth whereas growth affects uncertainty in a strongly significant and positive way. And the magnitude of the effect of volatility on growth is larger than that of the volatility effect of growth. Note that the effect of volatility on growth appears to be larger than that of uncertainty on growth. The evidence seems to accord with the argument that both anticipated and unanticipated components of volatility would incur costs that have negative impacts on economic growth.

As a further robustness check, we also experiment with the IH random effect estimation. Table 2 summarizes the results and continues to find a negative effect of volatility (uncertainty) on growth and a positive impact of growth on volatility (uncertainty), across alternative conditioning information sets. Table 2 overall shows qualitatively same results as Table 1 does.

Furthermore, we check whether the growth-volatility link is sensitive to the time period. It is well recognized that since 1980, a number of emerging markets and transition countries began to undertake trade and financial liberalization programs around this period; the dramatic surge in international financial flows across industrial countries as well as between industrial and developing countries got started; and the Great Moderation (the decline in business cycle volatility across all groups of countries, especially the industrial ones) began. In light of these facts, there may exist potential structural breaks in the link between growth and volatility. This paper explores this possibility and reports the IH fixed- and random-effect estimation results for the 1980-2007 period in Table 3 and 4.

Once again, the finding of negative growth effect of volatility and positive volatility impact of growth still holds, irrespective of alternative model specifications and econometric methods. The only exception is that the volatility effect of growth is significantly negative when applying the random effect estimation and using the simple conditioning set in Table 4. In addition, we find that growth uncertainty has much larger impact on economic growth than growth volatility does, suggesting that in this period, unanticipated component of growth volatility is more relevant in explaining the negative response of economic growth.

Our evidence of significant and negative growth effect of volatility confirms the finding of Ramey and Ramey (1995) and supports the hypothesis of irreversibility in investment and optimal waiting. It is also possible that greater uncertainty about the future reinforces capital market imperfection and hence prevents physical and human capital accumulation.[14] On the other hand, the finding of significant and positive impact of growth on volatility suggests that there exists feedbacks from growth to volatility and hence a failure to account for the endogeneity would result in biased conclusions. As a whole, our results point to the dynamic instability of stabilization policy in reducing economic fluctuations and hence improving growth as it would result in an unintended rise in output volatility.

3.2 Subsample Investigations

This section explores whether the interaction between economic growth and growth volatility varies with economic and financial conditions. It checks on nonlinearity in the interrelationship. The IH fixed-effect estimation results are reported in Table 5.[15] On balance, we find that across subsamples, output volatility indeed hinders economic growth after considering the reverse influence of growth on volatility. The data indeed reveal evidence for potential nonlinearity in the volatility-growth nexus.

First, we examine the effect of economic development on the volatility-growth nexus. As argued in Acemoglu and Zilibotti (1997), lower levels of economic development, by constraining the ability to diversify sector-specific risks, might lead to both higher volatility and lower growth. In other words, the negative relationship between growth and volatility might be more obvious in less developed countries. Our results in Panel A of Table 5 where countries are split into high-, medium- and low-income subsamples according to their initial income level indicate that a highly significant and negative growth effect of volatility coexists with a significant positive volatility impact of growth. An exception is the low-income group in which the positive effect of growth on volatility is not statistically significant. The evidence confirms our previous conclusions that growth volatility is detrimental to economic growth, even after controlling for the feedback from growth to volatility. Moreover, it shows that the respective effects of volatility and growth are stronger and more significant for the medium-income group.

Next, Panel B checks the effect of financial development on the

[14] See Hubbard (1998) for detailed discussion on how capital market imperfections affect investment.

[15] To save space, we only report the results using the full conditioning set for the 1960-2007 period. The results from alternative model specifications and for the 1980-2007 are available upon request.

growth-volatility relationship. Countries are divided into high-, medium- and low-financial-development groups according to the initial value of financial development measure. A highly significant and negative growth effect of volatility continues to be found for all country groups, while the significant feedback effect of growth on volatility vary with the level of financial development. And the negative growth effect of volatility seems to be largest in countries with medium degrees of financial development and lowest in countries with high financial development. The relatively large negative effects in countries with lower financial development is in line with Aghion *et al*. (2005), which to the extent that liquidity risk increases with aggregate volatility, volatility discourages long-term investment and slows down output growth, and the more so the tighter the credit constraints.

Panel C reports the results concerning whether the degree of trade openness affects the nexus between growth and volatility. We find a transition among the groups of countries with different trade openness. In countries with low and medium degrees of trade openness, both respective effects of volatility and growth are significant and negative. In high-openness countries, however, both of the effects turn significantly positive. Hence, the evidence indicates that, after considering the reverse causality, the influence of volatility on growth is negative for lower-openness countries and turns positive for countries with high levels of trade openness. It is consistent with Kose, Prasad and Terrones (2006), who find that trade openness has weakened the negative linkage between growth and volatility, implying that countries that are less open to trade flows may face a severe trade-off between growth and volatility.

Finally, Panel D checks whether the growth-volatility link varies with the level of inflation. Countries are split into high-, medium- and low-inflation regimes according to their initial level of inflation. We find that our main results remain intact. The growth effect of volatility is significant and negative while the volatility effect of growth is significantly positive, across all subsamples. And the data reveal that volatility has largest impacts on growth in high-inflation countries. It implies that inflation not only strengthens the negative effects of inflation on growth (Fischer, 1993; Barro, 1995; Bruno and Easterly, 1998), but also reinforces the negative impact of growth volatility on growth.

The results with the IH random-effect estimation for the same considerations as in Table 5 are summarized in Table 6. It in general shows results similar to those in Table 5. There very likely exist two-way interactions between growth and its volatility. And, while the volatility effect of growth varies across alternative subsamples, growth volatility appears to have adverse influence on economic growth.

4 Conclusions

The theoretical and empirical literature on the interrelationship between economic growth and growth volatility has not reached a consensus. The inconsistency among existing empirical studies is attributed to the simultaneity and joint determination biases. Average growth and its variability are two moments of the same underlying income process, and are likely to be jointly determined. Furthermore, because of feedback from volatility to growth and because mean growth and its variability have common underlying determinants, it is essential that one estimate a two-equation system to jointly explain both mean growth and volatility in growth. This paper revisits this issue and examines the growth-volatility nexus by applying the IH methodology of Rigobon (2003) to solve the identification problem of simultaneous equations model.

Based on a panel of 158 countries covering the period 1960-2007, our empirical result shows that growth volatility has a negative effect on economic growth after accounting for positive reverse causation from growth to volatility. The results are fairly consistent across alternative sets of conditioning variables, econometric methods, and time periods. The negative impact of growth on volatility thus confirms that more stable economies are more likely to grow faster, meaning that stabilization policy that mitigates business fluctuations would lead to higher economic growth. And the positive feedback of growth to volatility further suggests the need for continual stabilization efforts to maintain both growth and stability of the economy.

Reflecting nonlinearity in the growth-volatility nexus suggested in the literature, this study takes a step further and investigates whether the relationship varies with economic and financial conditions. The results considering different levels of economic and financial development, trade openness, and inflation provide suggestive evidence of nonlinearity in the nexus. It is noted that this paper does not formally and rigorously investigate the issue of nonlinearity. Since such an empirical assessment approximates specific conditions under which volatility hinders or stimulates growth, further study on the potential nonlinearity is needed to gain whole picture of the interrelationship between growth and volatility.

References

Acemoglu, D. and Johnson, S. (2005). Unbundling Institutions. *Journal of Political Economy* 113(5), 949-995.

Acemoglu, D., Johnson, S., Robinson, J. and Thaicharoen, Y. (2003). Institutional Causes, Macroeconomic Symptoms: Volatility, Crises and Growth. *Journal of Monetary Economics* 50, 49-123.

Acemoglu, D., Robinson, J. A. and Johnson, S. (2001). The Colonial Origins of Comparative Development: An Empirical Investigation. *American Economic Review* 91, 1369-1401.

Acemoglu, D. and Zilibotti, F. (1997). Was Prometheus Unbound by Chance? Risk, Diversification, and Growth. *Journal of Political Economy* 105, 709-751.

Aghion, P., Banerjee, A. V., Angeletos, G.-M. and Manova, K. (2005). Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment. *NBER Working Paper* No. W11349.

Aghion, P., Banerjee, A.V. and Piketty, T. (1999). Dualism and Macroeconomic Volatility. *Quarterly Journal of Economics* 114(4), 1359-1397.

Aizenman, J. and Marion, N. (1993). "Policy Uncertainty, Persistence and Growth." *Review of International Economics* 1, 145-163.

Aizenman, J. and Marion, N. (1999). Volatility and Investment: Interpreting Evidence from Developing Countries. *Economica* 66, 157-179.

Barro, R. J. (1995). Inflation and Economic Growth. *Bank of England Quarterly Bulletin*, 166-176.

Bhattacharyya, S. (2009). Unbundled Institutions, Human Capital and Growth. *Journal of Comparative Economics* 37(1), 106-120.

Black, F. (1987). *Business Cycles and Equilibrium*. New York: Blackwell.

Blackburn, K. (1999). Can Stabilisation Policy Reduce Long-Run Growth? *Economic Journal* 109(452), 67-77.

Blackburn, K. and Pelloni, A. (2005). Growth, Cycles, and Stabilization Policy. *Oxford Economic Papers* 57, 262-282.

Bohl, M. T., P. L. Siklos and T. Werner. 2007. Do central banks react to the stock market? The case of the Bundesbank. *Journal of Banking and Finance* 31: 719-733.

Bose, N. and Murshid, A. P. (2008). Mitigating the Growth-Effects of Inflation through Financial Development. *The B.E. Journal of Macroeconomics* 8 (1), Article 8.

Bound, J., Jaeger, D. A. and Baker, R. M. (1995). Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak. *Journal of the American Statistical Association* 90, 443-450.

Bredin, D., Elder, J. and Fountas, S. (2009). Macroeconomic Uncertainty and Performance in Asian countries. *Review of Development Economics* 13(2), 215-229.

Bruno, M. and Easterly, W. (1998). Inflation Crises and Long-Run Growth. *Journal of Monetary Economics* 41, 3-26.

Bullard, J. B. and Keating, J. W. (1995). The Long-Run Relationship between Inflation and Output in Postwar Economies. *Journal of Monetary Economics* 36, 477-496.

Caporale, G. M., Cipollini, A. and Demetriades, P. O. (2005). Monetary policy and the exchange rate during the Asian crisis: Identification through heteroskedasticity. *Journal of International Money and Finance* 24, 39-53.

Caporale, T. and McKiernan, B. (1998). The Fischer Black Hypothesis: Some Time-Series Evidence. *Southern Economic Journal* 64, 765-771.

Chong, A. and Gradstein, M. (2009). Volatility and Firm Growth. Journal of Economic Growth 14, 1-25.

Edwards, J.A. and Thames, F.C. (2009). The Effects of Economic and Political Development on GDP Growth Volatility. *Global Economy Journal* 9(2), Article 1. doi**:** 10.2202/1524-5861.1452.

Easterly, W. (2005). National Policies and Economic Growth. In P. Aghion and S. Durlauf (EDs.), Handbook of Economic Growth. Elsevier.

Easterly, W. and Levine, R. (2003). Tropics, Germs, and Crops: The Role of Endowment in Economic Development. *Journal of Monetary Economics* 50(1), 3-39.

Fatas, A. (2002). The Effects of Business Cycles on Growth. In N. Loayza and R. Soto, eds., *Economic Growth: Sources, Trends and Cycles*. Santiago: Central Bank of Chile.

Fatas, A. and Mihov, I. (2006). Policy Volatility, Institutions and Economic Growth. *CEPR Discussion Paper* No. 5388.

Fischer, S. (1993). The Role of Macroeconomic Factors in Growth. *Journal of Monetary Economics* 32, 485-511.

Fountas, S. and Karanasos, M. (2006). The Relationship between Economic Growth and Real Uncertainty in the G3. *Economic Modelling* 23, 638-647.

Fountas, S., Karanasos, M. and Kim, J. (2002). Inflation and Output Growth Uncertainty and Their Relationship with Inflation and Output Growth. *Economics Letters* 75, 293-301.

Fountas, S., Karanasos, M. and Kim, J. (2006). Inflation Uncertainty, Output Growth

Uncertainty and Macroeconomic Performance. *Oxford Bulletin of Economics and Statistics* 68, 319-343.

Gillman, M. (2005). Contrasting Models of the Effect of Inflation on Growth. *Journal of Economic Surveys* 19, 113-136.

Grier, K. B., Henry, O. T., Olekalns, N. and Shields, K. (2004). The Asymmetric Effects of Uncertainty on Inflation and Output Growth. *Journal of Applied Econometrics* 19, 551-565.

Grier, K. B. and Perry, M. J. (2000). The Effects of Real and Nominal Uncertainty on Inflation and Output Growth: Some GARCH-M Evidence. *Journal of Applied Econometrics 1*5, 45-58.

Grier, K. B. and Tullock, G. (1989). An Empirical Analysis of Cross-national Economic Growth, 1951-1980. *Journal of Monetary Economics* 24(2), 259-276.

Hall, R. E. and Jones, C. I. (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics* 114, 83-116.

Henry, O. and Olekalns, N. (2000). The Effects of Recessions on the Relationship between Output Variability and Growth. *Southern Economic Journal* 68, 683-692.

Hnatkovska, V. and Loayza, N. (2005). Volatility and Growth. In J. Aizenman and B. Pinto, eds., *Managing Economic Volatility and Crises: A Practitioner's Guide*. Cambridge: Cambridge University Press.

Hopenhayn, H. A. and Muniagurria, M. E. (1996). "Policy Volatility and Economic Growth." *Review of Economic Studies* 63.

Hubbard, R. G. (1998). Capital-Market Imperfections and Investment. *Journal of Economic Literature* 36, 193-225.

Imbs, J. (2007). Growth and Volatility. Journal of Monetary Economics 54, 1848-1862.

Khan, M. S. and Senhadji, A. S. (2001). Threshold Effects in the Relationship between Inflation and Growth. *IMF Staff Papers* 48, 1-21.

Knack, S and Keefer, P. (1995). Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures. *Economics and Politics* 7(3), 207-227.

Kormendi, R. C. and Meguire, P. (1985). Macroeconomic Determinants of Growth: Cross-country Evidence. *Journal of Monetary Economics* 16(2), 141-163.

Kose, M. A., Prasad, E. S. and Terrones, M. E. (2006). How Do Trade and Financial Integration Affect the Relationship between Growth and Volatility? *Journal of International Economics* 69, 176-202.

Lee, H. Y., Ricci, L. A. and Rigobon, R. (2004). Once again, is openness good for growth? *Journal of Development Economics* 75, 451-472.

Levine R. (1997). Financial development and economic growth: Views and agenda. *Journal of Economic Literature* 35, 688-726.

Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion and S. N. Durlauf, eds., *Handbook of Economic Growth*. Amsterdam: Elsevier.

Malik, A. and Temple, J. R. W. (2008). The Geography of Output Volatility. *Journal of Development Economics*, doi:10.1016/j/jdeveco.2008.10.003.

Martin, P. and Rogers, C. A. (2000). Long-Term Growth and Short-Term Economic Instability. *European Economic Review* 44(2), 359-381.

Mirman, L. J. (1971). Uncertainty and Optimal Consumption Decisions. *Econometric*a 39(1), 179-185.

Pindyck, R. S. (1991). Irreversibility, Uncertainty, and Investment. *Journal of Economic Literature* 29(3), 1110-1148.

Rafferty, M. (2005). The Effects of Expected and Unexpected Volatility on Long-Run Growth: Evidence from 18 Developed Economies. *Southern Economic Journal* 71, 582-591.

Ramey, G. and Ramey, V. A. (1991). Technology Commitment and the Cost of Economic Fluctuations. *NBER Working Paper* No. 3755.

Ramey, G. and Ramey, V. A. (1995). Cross-Country Evidence on the Link between Volatility and Growth. *American Economic Review* 85, 1138-1151.

Rigobon, R. (2003). Identification through heteroskedasticity. *Review of Economics and Statistics* 85, 777-792.

Rigobon, R. and Rodrik, D. (2005). Rule of law, democracy, openness, and income: Estimating the interrelationships. *Economics of Transition* 13, 533-564

Rigobon, R. and Sack, B. (2003). Measuring the reaction of monetary policy to the stock market. *Quarterly Journal of Economics* 118, 639-669.

Rodrik, D., Subramanian, A. and Trebbi, F. (2004). Institutions rule: The primacy of institutions over geography and integration in economic development. *Journal of Economic Growth* 9, 131-165.

Speight, A. (1999). UK Output Variability and Growth: Some Further Evidence. *Scottish Journal of Political Economy* 46, 175-184.

Table 1: IH Fixed-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0126*** (0.0012)		0.0064*** (0.0014)		0.0027** (0.0014)
volatility	-0.8398*** (0.0213)		-0.5163*** (0.0235)		-0.4148*** (0.0240)	
Obs.	1056		941		929	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0089*** (0.0011)		0.0123*** (0.0018)		0.0176*** (0.0017)
uncertainty	-0.2710*** (0.0192)		-0.1237*** (0.0251)		-0.1833*** (0.0248)	
Obs.	1052		935		923	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 2: IH Random-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0166*** (0.0012)		0.0058*** (0.0014)		0.0028** (0.0013)
volatility	-0.9794*** (0.0213)		-0.5444*** (0.0229)		-0.4432*** (0.0222)	
Obs.	1056		941		929	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0115*** (0.0011)		0.0165*** (0.0015)		0.0184*** (0.0014)
uncertainty	-0.4586*** (0.0198)		-0.4021*** (0.0236)		-0.4117*** (0.0229)	
Obs.	1052		935		923	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 3: IH Fixed-Effect Estimates of Growth and Volatility (1980-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0063*** (0.0014)		0.0120*** (0.0022)		0.0096*** (0.0023)
volatility	-0.7532*** (0.0227)		-0.6510*** (0.0291)		-0.6126*** (0.0315)	
Obs.	724		674		668	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0247*** (0.0016)		0.0475*** (0.0028)		0.0511*** (0.0028)
uncertainty	-0.8941*** (0.0285)		-0.9901*** (0.0407)		-1.0466*** (0.0422)	
Obs.	723		671		665	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 4: IH Random-Effect Estimates of Growth and Volatility (1980-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		-0.0047*** (0.0012)		0.0131*** (0.0022)		0.0108*** (0.0022)
volatility	-0.6159*** (0.0243)		-0.6951*** (0.0317)		-0.6780*** (0.0318)	
Obs.	724		674		668	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0153*** (0.0013)		0.0324*** (0.0023)		0.0343*** (0.0022)
uncertainty	-1.1155*** (0.0287)		-1.0600*** (0.0418)		-1.1293*** (0.0423)	
Obs.	723		671		665	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 5: IH Fixed-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Economic Development

	Low-income		*Mid-Income*		*High-Income*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0019 (0.0109)		0.0763*** (0.0043)		0.0113* (0.0070)
volatility	-0.3540*** (0.1343)		-1.6023*** (0.0799)		-0.2525*** (0.0648)	
Obs.	284		314		331	

Panel B: Financial Development

	Low-financial-development		*Mid-financial development*		*High-financial development*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0343*** (0.0049)		-0.0287*** (0.0112)		0.0247*** (0.0103)
volatility	-0.2890*** (0.1040)		-0.5285*** (0.1681)		-0.2037*** (0.0756)	
Obs.	264		334		331	

Panel C: Trade Openness

	Low-trade-openness		*Mid-trade-openness*		*High-trade-openness*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0355*** (0.0057)		-0.0062* (0.0040)		0.0172*** (0.0042)
volatility	-0.2478*** (0.0633)		-0.2655*** (0.0663)		0.2827*** (0.0623)	
Obs.	359		321		249	

Panel D: Inflation

	Low-inflation		Mid-inflation		High-inflation	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0599*** (0.0030)		0.0136** (0.0073)		0.0199*** (0.0056)
volatility	-0.6332*** (0.0536)		-0.1183* (0.0815)		-1.1678*** (0.1014)	
Obs.	302		354		273	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured by the standard deviation of output growth (*volatility*). The full conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), the rate of population growth (*popg*), government expenditure as a share of GDP (*gov*), inflation rate (*inf*), trade openness (*trade*) and financial development (*privo*) indicators, and period- and country-dummies. The standard errors are in parentheses. ***, **, and * denotes significant at 1 %, 5%, and 10% level, respectively.

Table 6: IH Random-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Economic Development

	Low-income		*Mid-Income*		*High-Income*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0041 (0.0071)		0.0737*** (0.0064)		0.0085** (0.0051)
volatility	-0.3823*** (0.0825)		-1.8384*** (0.1066)		-0.2134*** (0.0613)	
Obs.	284		314		331	

Panel B: Financial Development

	Low-financial-development		*Mid-financial development*		*High-financial development*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0339*** (0.0040)		0.0107* (0.0079)		0.0018 (0.0095)
volatility	-0.4434*** (0.0859)		-1.0523*** (0.1191)		-0.0626 (0.0695)	
Obs.	264		334		331	

Panel C: Trade Openness

	Low-trade-openness		*Mid-trade-openness*		*High-trade-openness*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0279*** (0.0044)		-0.0049 (0.0042)		-0.0089** (0.0039)
volatility	-0.2555*** (0.0532)		-0.3620*** (0.0655)		0.5450*** (0.0591)	
Obs.	359		321		249	

Panel D: Inflation

	Low-inflation		Mid-inflation		High-inflation	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0319*** (0.0027)		0.0257*** (0.0066)		0.0058 (0.0048)
volatility	-0.3393*** (0.0470)		-0.3018*** (0.0799)		-1.0990*** (0.0941)	
Obs.	302		354		273	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured by the standard deviation of output growth (*volatility*). The full conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), the rate of population growth (*popg*), government expenditure as a share of GDP (*gov*), inflation rate (*inf*), trade openness (*trade*) and financial development (*privo*) indicators, and period- and country-dummies. The standard errors are in parentheses. ***, **, and * denotes significant at 1 %, 5%, and 10% level, respectively.

Appendix

Table A1: A List of Sample Countries

AGO	COL	HRV	MEX	SGP
ALB	CPV	HTI	MKD	SLE
ARG	CRI	HUN	MLI	SLV
ARM	CYP	IDN	MNG	SUR
AUS	CZE	IND	MOZ	SVK
AUT	DEU	IRL	MRT	SVN
AZE	DMA	IRN	MUS	SWE
BDI	DNK	ISL	MWI	SWZ
BEL	DOM	ISR	MYS	SYC
BEN	DZA	ITA	NER	SYR
BFA	ECU	JAM	NGA	TCD
BGD	EGY	JOR	NIC	TGO
BGR	ESP	JPN	NLD	THA
BHR	EST	KAZ	NOR	TON
BHS	ETH	KEN	NPL	TTO
BLR	FIN	KGZ	NZL	TUN
BLZ	FJI	KNA	OMN	TUR
BOL	FRA	KOR	PAK	UGA
BRA	GAB	KWT	PAN	UKR
BRB	GBR	LAO	PER	URY
BRN	GEO	LBN	PHL	USA
BTN	GHA	LCA	PNG	VCT
BWA	GMB	LKA	POL	VEN
CAF	GNB	LSO	PRT	VNM
CAN	GNQ	LTU	PRY	VUT
CHE	GRC	LUX	ROM	YEM
CHL	GRD	LVA	RUS	ZAF
CHN	GTM	MAC	RWA	ZAR
CIV	GUY	MAR	SAU	ZMB
CMR	HKG	MDA	SDN	ZWE
COG	HND	MDG	SEN	
AGO	COL	HRV	MEX	

Table A2: Descriptive statistics (1960-2007)

Panel A: Summary Statistics

	growth	*volatility*	*uncertainty*	*igdp*	*inv*	*popg*	*trade*	*gov*	*inf*	*privo*
Mean	3.8413	1.0312	2.5434	7.4739	3.0183	1.7597	4.1065	2.6646	0.1575	3.2138
Median	3.8326	1.0465	2.5607	7.3601	3.0504	1.9124	4.1303	2.6788	0.0700	3.2345
Std.	3.8987	0.8055	1.1922	1.5353	0.3522	1.8001	0.6033	0.3958	0.3635	0.9415
Max.	38.5745	3.8873	7.6639	10.9884	4.4194	10.5462	6.0342	4.0325	4.1922	5.3980
Min.	-20.6200	-4.8493	-1.3919	4.3524	1.1581	-44.4084	1.6704	1.2578	-0.0435	-0.0033
Obs.	1178	1171	1170	1205	1089	1386	1163	1168	1062	1115

Panel B: Correlation

growth	1.0000									
volatility	-0.0676	1.0000								
uncertainty	0.0022	0.6717	1.0000							
igdp	-0.0584	-0.2463	-0.3476	1.0000						
inv	0.3150	-0.1126	-0.1072	0.3294	1.0000					
popg	0.0608	0.0688	0.1150	-0.3230	-0.1353	1.0000				
trade	0.0554	0.0318	0.0556	0.2147	0.3670	-0.1414	1.0000			
gov	-0.1387	0.0165	-0.0148	0.3714	0.2040	-0.2157	0.3827	1.0000		
inf	-0.3865	0.2059	0.1511	-0.1031	-0.1234	-0.0347	-0.0848	-0.0237	1.0000	
privo	0.0032	-0.3280	-0.3800	0.7126	0.3788	-0.2207	0.2236	0.3226	-0.2220	1.0000

Table A3: OLS Fixed-Effect Estimates of Growth and Volatility (1960-2007)

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0154**		-0.0139*		-0.0137
		(0.0069)		(0.0084)		(0.0085)
volatility	-0.3618**		-0.2537*		-0.2504	
	(0.1618)		(0.1535)		(0.1549)	
constant	14.9873***	1.9920***	24.2826***	0.5969	26.2618***	0.8254
	(2.9868)	(0.6221)	(3.6377)	(0.8753)	(3.7223)	(0.8982)
igdp	-3.2693***	-0.0087	-4.0084***	0.0426	-4.0788***	0.0663
	(0.3979)	(0.0853)	(0.4312)	(0.1064)	(0.4520)	(0.1112)
inv	4.8469***	-0.1998**	3.7490***	-0.2678**	3.8128***	-0.2486**
	(0.4384)	(0.0963)	(0.4527)	(0.1101)	(0.4619)	(0.1124)
popg	-0.0988	-0.0308**	-0.1823***	-0.0276**	-0.1835***	-0.0264**
	(0.0618)	(0.0127)	(0.0565)	(0.0133)	(0.0566)	(0.0133)
trade			1.7135***	0.3400***	1.7725***	0.3550***
			(0.5141)	(0.1206)	(0.5159)	(0.1209)
gov			-2.7730***	-0.0456	-2.8179***	-0.0217
			(0.5082)	(0.1212)	(0.5244)	(0.1250)
inf			-3.6233***	0.1714**	-3.6080***	0.1667**
			(0.3255)	(0.0818)	(0.3287)	(0.0825)
privo					-0.2336	-0.0782
					(0.2512)	(0.0587)
Obs	1056		941		929	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. To save space, the estimates for dummies are not reported but available upon request. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table A4: OLS Random-Effects Estimates of Growth and Volatility (1960-2007)

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0145**		-0.0095		-0.0096
		(0.0064)		(0.0075)		(0.0075)
volatility	-0.2860*		-0.1249		-0.1518	
	(0.1480)		(0.1422)		(0.1450)	
constant	-3.3549***	2.4824***	0.8106	1.4264***	1.9047***	1.9395***
	(1.2399)	(0.2677)	(1.4019)	(0.3472)	(1.5491)	(0.3651)
igdp	-0.4750***	-0.1215***	-0.5126***	-0.1374***	-0.3875***	-0.0721**
	(0.0955)	(0.0238)	(0.0975)	(0.0254)	(0.1229)	(0.0302)
inv	4.3025***	-0.1061	3.9407***	-0.2132**	4.0442	-0.1487
	(0.3577)	(0.0824)	(0.3635)	(0.0914)	(0.3717)	(0.0919)
popg	0.0379	-0.0221*	-0.0813	-0.0199	-0.0834	-0.0167
	(0.0590)	(0.0120)	(0.0545)	(0.0125)	(0.0548)	(0.0124)
trade			0.3895	0.3175***	0.4261***	0.3044***
			(0.2559)	(0.0648)	(0.2593)	(0.0628)
gov			-1.6188***	0.0838	-1.6165***	0.1188
			(0.3546)	(0.0878)	(0.3607)	(0.0867)
inf			-3.4537***	0.2692***	-3.5256***	0.2322***
			(0.2982)	(0.0730)	(0.3046)	(0.0739)
privo					-0.3128*	-0.1655***
					(0.1875)	(0.0439)
Obs	1056		941		929	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. To save space, the estimates for dummies are not reported but available upon request. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

計畫成果:

就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

(1) 因計劃由兩年期刪為一年期，故研究重心放在經濟成長與其不確定性之關聯研究上。如同在計畫案中所言，我們建立聯立方程式並利用Rigobon's 變異數異質性確定法進行估計。如預期，我們發現經濟成長不確定性對經濟成長具顯著為負之影響，當適當控制內生問題。其意謂政府反景氣循環之政策不但可緩和景氣之波動，亦可達成長期經濟成長之功效。
(2) 基於其政策之重要性，與結果之穩健性，適合發表在不錯之國際學術期刊。
(3) 本研究亦發現經濟成長與其不確定性非線性之可能，進一步相關正式計量方法的檢定可幫助釐清問題。

The Link between Economic Growth and Growth Volatility

Dong-Hyeon Kim*
Department of Finance, Providence University

and

Shu-Chin Lin
Department of Economics, Tamkang University

* Corresponding author: Dong-Hyeon Kim, Finance, Providence University, 200 Chung-Chi Road, Taichung 43301, Taiwan, R.O.C. Tel: +886-4-26328001 ext. 13608; Fax: +886-4-26311222; Email: dhkim@pu.edu.tw. The authors are grateful to R. Rigobon for kindly making available computer code, James Yang for his excellent research assistance, and financial support from NSC. Any remaining errors are our own responsibility.

Economic Growth and Growth Volatility Revisited

Abstract

This paper investigates the relationship between economic growth and growth volatility through simultaneous equations system. By employing the identification through Heteroskedasticity method of Rigobon (2003) and using a panel of 158 countries over the period of 1960-2007, we find that output volatility is detrimental to economic growth, suggesting that stabilization policies to mitigate short-run economic fluctuations contribute to long-run economic growth. We also find that economic growth accelerates output variability, supporting the feedback effects from growth to the volatility. The evidence is robust to a number of sensitivity tests. In addition, when splitting the data into different subsamples according to the attributes of countries, we find that while the growth effect on volatility varies, a negative impact of volatility on growth continues to hold.

Keywords: Economic Growth, Growth Volatility, Simultaneous equations model, Identification through heteroskedasticity

JEL Classification: C33, N10, O50

1. Introduction

Recently, much attention has been directed to the issue of whether macroeconomic volatility affects economic performance, particularly to the relationship between economic growth and growth volatility.[1] Traditionally, business cycle and economic growth models are treated as different doctrines in the sense that short-run economic fluctuations and long-run economic growth are determined independently in different time horizons. However, since the influential work of Ramey and Ramey (1995) that finds a significant effect of growth volatility on economic growth, considerable and growing effort has been devoted to the link between these two variables. The evidence of significant effects of growth volatility has important policy implications for the determination of economic growth. It provides a channel through which short-term government policies may influence long-term output growth. If, for example, growth volatility is found to affect economic growth positively, short-run stabilization may be detrimental to long-run growth such that the government confronts tradeoffs between short-term stability and long-run economic growth. If, instead, growth volatility tends to influence growth negatively, stabilization policies may improve economic growth.

However, the theoretical literature on the relationship between economic growth and growth volatility is still far from being uncontroversial. The literature on irreversible investment and the option value of waiting predicts a negative relationship between growth uncertainty and average growth. In these models, an increase in uncertainty about future profit raises the value of waiting, thus delaying investment and lowering growth (e.g., Pindyck, 1991; Ramey and Ramey, 1991). In

[1] The growing literature also emphasizes potential impacts of volatility on inequality and investment. Growth volatility is said to strengthen the gap between the rich and the poor, as the poor may lack the liquid wealth or access to credit that would be needed to smooth consumption. And the uncertainty associated with short-run output variations can translate into lower investment (Aizenman and Marion, 1999)

contrast, there is an argument attributable to Black (1987) that implies a positive relationship. This is based on the assumptions that technology choices are made from a menu of possibilities where the average rate of return (growth) and return volatility (growth volatility) are positively correlated, and that technology which produces faster average growth is inherently riskier. Another argument in favor of a positive relationship between growth and volatility comes from the theory of precautionary savings where increased risk raises desired saving and hence investment and growth (Mirman, 1971). Furthermore, proponents of endogenous growth theory assert that the relationship between growth and volatility depends on whether productivity-improving activity and production are substitutes or complements.[2]

This conflict in theoretical predictions is reflected in the empirical literature. In cross-section studies, Kormendi and Meguire (1985) and Grier and Tullock (1989) are among the earliest studies to directly examine the growth-volatility relationship and report a positive relationship. However, Ramey and Ramey (1995) find that growth and volatility are negatively related. Subsequent studies such as Martin and Rogers (2000), Fatas (2002), Hnatkovska and Loayza (2005), Rafferty (2005), and Aghion, Banerjee, Angeletos, and Manova (2005) also find similar results.[3] Studies based on time series data also reach mixed, if not contradictory, conclusions, depending on the time period, the frequency, and the countries considered (though most studies are concentrated on industrialized countries). For example, using US data, Caporale and McKieman (1998), Grier and Perry (2000), and Grier, Henry, Olekalns, and Shields (2004) obtain evidence for positive effect of output uncertainty on growth, while Henry and Olekalns (2002) support the negative effect. Speight (1999) and Fountas,

[2] See Blackburn (1999), Martin and Rogers (2000), and Blackburn and Pelloni (2005) for discussions.

[3] There is emerging research presenting disaggregated evidence. Imbs (2007) shows that volatility promotes growth at the firm level. By contrast, Chong and Gradstein (2009) find that volatility is detrimental to firm growth, and such an adverse effect is magnified by institutional obstacles.

Karanasos and Kim (2002) finds no significant growth effects in the UK and Japan, respectively. Others including Fountas and Karanasos (2006) and Fountas, Karanasos and Kim (2006) find mixed results from the G3 and G7 countries, respectively. In a sample of Asian Countries, Bredin, Elder and Fountas (2009) find that uncertainty regarding the output growth rate is related negatively to the average growth rate.

One of the main criticisms on existing empirical works is that growth and volatility are endogenously and jointly determined. For example, if an increase in output growth leads to more inflation, and if inflation causes a rise in inflation uncertainty, then a higher growth may lead a lower growth uncertainty, given that inflation uncertainty and growth uncertainty are substitute. However, if the monetary authorities respond inflation pressure by monetary contraction which reduces both inflation and inflation uncertainty, then output growth increases growth volatility. Alternatively, as important determinants of economic growth, a large literature points to domestic policy management (such as inflation, openness and fiscal deficits),[4] the role of financial systems (such as banking and stock market development),[5] and more general institutional attributes (such as legal origins, settler mortality and property rights) and geographic characteristics (such as natural resource endowments, market access and climate variability).[6] These factors are also attributed to cross-country differences in growth volatility.[7] Therefore, the finding of a positive or negative link between growth and volatility may simply reflect a reverse causation from volatility to growth or a common driving forces rather than a causal relationship. [8]

[4] See Gillman (2005) for theoretical discussions, and Barro (1995), Bullard and Keating (1995), Bruno and Easterly (1998), Khan and Senhadji (2001), and Bose and Murshid (2008), among others, for empirical investigations on the link between growth and inflation.
[5] See Levine (1997, 2005) for detailed discussions and references therein.
[6] See Knack and Keefer (1995), Hall and Jones (1999), Acemoglu, Robinson and Johnson (2001), Acemoglu and Johnson (2005), Easterly and Levine (2003), Rodrik, Subramanian and Trebbi (2004), and Bhattacharyya (2009), to name a few.
[7] See Malik and Temple (2008) for detailed discussions and references therein.
[8] Related literature postulates that economic development will mitigate growth volatility. It is argued that less-developed countries are more volatile because of their relatively unsophisticated financial

In this respect, this paper intends to make a contribution to the literature by providing empirical relevance to the growth-volatility correlation through a simultaneous equations model (SEM) in which the endogenous and joint determination of the two variables can be adequately addressed. And it considers the dynamics of stabilization policy in the phase of economic development. As it is known, however, an unrestricted SEM is underidentified so that structural parameters cannot be recovered into nontrivial solutions from reduced-form estimates. The problem of identification must be solved before estimation.

For this issue, it is conventional to impose *a priori* exclusion, sign, long-run, or covariance restrictions. As the empirical literature on the growth-volatility nexus implies, however, the exclusion, sign, and long-run restrictions are not suitable to this study. The sign and magnitude of the contemporaneous coefficients are main empirical matters. And near identification by covariance restriction does not apply to this case with sample heteroskedasticity. Another useful way is the instrumental variable approach. The method amounts to find valid instruments that are uncorrelated with the error term but correlated with the endogenous explanatory variable. However, it is difficult to come up with valid instruments for cross-country studies. And as shown in Bound, Jaeger and Baker (1995), weak instruments can lead to large inconsistency in parameter estimates even if the instruments are only weakly correlated with errors in structural equation.

---

markets. For example, Acemoglu and Zilibotti (1997) argue that weakly developed economies lack significant diversification. The absence of opportunities for diversification prevents agents from spreading risk as a hedge against shocks. Aghion, Banerjee, and Piketty (1999) establish a related theoretical link between low financial sector development and high volatility. Their model shows that a sharper separation between savers and investors results in greater volatility. One characteristic of a lesser-developed economy may be the lack of the skills and connections needed for someone to partake in successful investment opportunities, thus preventing them from hedging against shocks. However, as economies develop, incomes, investment, and education levels should increase. This will lead to an increase in financial deepening, industry diversification, and more savvy savers who exploit more diversified investment opportunities. Consequently, one would expect that as the level of economic development increases, the level of GDP growth volatility will decrease. Edwards and Thames (2009) provide empirical evidence of this sort.

Since the standard identification methodologies are not useful to this study, we rely on an alternative method called ‘identification through heteroskedasticity (IH henceforth)’ of Rigobon (2003),[9] to examine the coevolution between economic growth and growth volatility across countries and over time. The IH approach exploits the difference (heteroskedasticity) in the structural variances of subsamples to gain identification. Since sample heteroskedasticity is observed in both economic growth and the volatility, the IH method solves the identification problem with an assumption of coefficient stability,[10] as proposed and proved by Rigobon (2003).

Our empirical results based on a large dataset including 158 countries over 1960-2007 show that after accounting for the feedback effect of growth on volatility, heightened growth volatility would hinder economic growth. We also find that faster economic growth would result in more volatile output growth. The evidence is robust to alternative sets of conditioning variables, econometric methods, and time periods. However, when splitting the data into country subsamples according to the level of income, financial development, trade openness, and inflation, we find that while the growth effect on volatility varies, a negative impact of volatility on growth continues to hold. Overall, the data highlight a negative effect of volatility on growth and indicate the need for stabilization policies to smooth volatility and promote output growth.

Our study is related to the literature on policy volatility and economic growth. Acemoglu *et al.* (2003) and Easterly (2005) argue that macroeconomic policy has an explanatory power for the cross-country variation in growth rates and per capita

[9] Since its introduction with an analysis of the contemporaneous relationship between returns on Argentinean, Brazilian, and Mexican sovereign bonds (Rigobon, 2003), the IH approach has been employed to estimate the reaction of monetary policy to the stock market (Rigobon and Sack, 2003; Bohl, Siklos and Werner, 2007), to examine the effect of openness on growth (Lee, Ricci and Rigobon, 2004), to investigate the interrelationships among economic institutions, political institutions, openness, and income level (Rigobon and Rodrik, 2005), to assess the relationship between exchange rates and interest rates (Caporale, Cipollini, and Demetriades, 2005), and so on.

[10] As discussed in Rigobon (2003), this assumption is implicit in many econometric methodologies.

income only because they serve as a proxy for institutions. And, Fatas and Mihov (2006) posit that a key policy characteristic that matters for the long-term country performance is the volatility and present evidence in support of that policy volatility exerts a strong and direct negative impact on growth. Similar results are also found in Aizenman and Marion (1993) and Hopenhayn and Muniagurria (1996).

The remainder of the paper is organized as follows. Section 2 illustrates the identification problem, introduces the IH approach, and describes the data. Section 3 analyzes empirical results. And Section 4 concludes the paper.

2 Econometric Methodology and Data

2.1 Identification through Heteroskedasticity

A simultaneous equations model (SEM) describing the interrelationship between economic growth (*g*) and growth volatility (*vol*) is formed as

$$\begin{aligned} g &= \beta_1 vol + \varepsilon_1 \\ vol &= \beta_2 g + \varepsilon_2 \end{aligned} \tag{1}$$

where $\varepsilon_i \sim \left(0, \sigma_i^2\right)$, i = 1 and 2, are the structural shocks to the 'growth' and 'volatility' regressions, and assumed to be contemporaneously and serially uncorrelated. In matrix form, model (1) is rewritten as

$$\begin{bmatrix} 1 & -\beta_1 \\ -\beta_2 & 1 \end{bmatrix} \begin{bmatrix} g \\ vol \end{bmatrix} = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix}$$

or

$$BY = \varepsilon \tag{2}$$

where the coefficient matrix B measures the contemporaneous relationship among the endogenous variables in the vector Y. Since the error term $\varepsilon = (\varepsilon_1, \varepsilon_2)'$ is assumed to be uncorrelated, the covariance matrix is

$$V(\varepsilon) = \Sigma = \begin{bmatrix} \sigma_1^2 & 0 \\ 0 & \sigma_2^2 \end{bmatrix} \quad (3)$$

Then, the reduced form is

$$Y = B^{-1}\varepsilon \quad (4)$$

with the reduced-form residual η given as

$$\eta = B^{-1}\varepsilon \quad (5)$$

The covariance matrix of the reduced-form innovations is

$$V(\eta) = B^{-1}\Sigma B^{-1'} = \Omega \quad (6)$$

As it is well known, the reduced-form equations in (4) can be consistently estimated by OLS, while the structural regressions in (2) cannot be.

The problem of identification concerns if the structural parameters can be recovered from the reduced-form estimates. It is generally impossible because the unrestricted SEM is underidentified.[11] There are solutions for the problem of identification such as imposition of restrictions on structural parameters and the instrumental variable approach. However, the standard methodologies are often inapplicable to applied economic studies. As an alternative, Rigobon (2003) suggests appealing to heteroskedasticity in the structural shocks to obtain identification of the simultaneous system. The idea of the IH approach is to increase the number of moment conditions so that the order and rank conditions can be satisfied. Assuming there are two regimes with different relative variance of the structural shocks, there are two reduced-form covariance matrices as

---

[11] There are 4 unknowns to be estimated: 2 structural parameters in B and 2 unknown variances of the structural shocks in Σ. However, the estimated covariance matrix of the reduced-form residuals, $\hat{\Omega}$, provides only $2(2+1)/2 = 3$ moment conditions. The standard identification problem arises since there are fewer equations (moments) than the number of unknowns.

$$\hat{\Omega}_1 = B^{-1}\Sigma_1 B^{-1'}$$
$$\hat{\Omega}_2 = B^{-1}\Sigma_2 B^{-1'}$$

Or specifically,

$$\begin{bmatrix} \omega_{g,1}^2 & \omega_{gvol,1} \\ \cdot & \omega_{vol,1}^2 \end{bmatrix} = \begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \sigma_{g,1}^2 & 0 \\ 0 & \sigma_{vol,1}^2 \end{bmatrix} \begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1'}$$
$$\begin{bmatrix} \omega_{g,2}^2 & \omega_{gvol,2} \\ \cdot & \omega_{vol,2}^2 \end{bmatrix} = \begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \sigma_{g,2}^2 & 0 \\ 0 & \sigma_{vol,2}^2 \end{bmatrix} \begin{bmatrix} 1 & -B_1 \\ -B_2 & 1 \end{bmatrix}^{-1'}$$

Hence there are 6 moment conditions equating $\omega_{g,1}^2$, $\omega_{gvol,1}$, $\omega_{vol,1}^2$, $\omega_{g,2}^2$, $\omega_{gvol,2}$, and $\omega_{vol,2}^2$ to their right-hand side counterparts. Then the 6 moments can be used to estimate the 2 structural parameters (β_1 and β_2) and the 4 variances of the structural shocks in two subsamples ($\sigma_{g,1}^2$, $\sigma_{vol,1}^2$, $\sigma_{g,2}^2$, and $\sigma_{vol,2}^2$). Moreover, Rigobon (2003) proves thoroughly that the IH method solves the problem of identification for the cases with more than two regimes, with common shocks, and even with misspecified heteroskedasticity.

With relevant explanatory variables added, the SEM of the growth-volatility nexus is

$$g = \beta_1 vol + x'\alpha_1 + \varepsilon_1$$
$$vol = \beta_2 g + x'\alpha_2 + \varepsilon_2$$

or

$$BY = \Gamma x + \varepsilon \qquad (7)$$

where x is a vector of relevant explanatory (control) variables common in both equations, and

$$\Gamma = \begin{bmatrix} \gamma_1' & 0 \\ 0 & \gamma_2' \end{bmatrix}$$

The reduced form is

$$Y = B^{-1}\Gamma x + \eta \qquad (8)$$

The consistent estimates of $\eta = B^{-1}\varepsilon$ and $B^{-1}\Gamma$ can be obtained by OLS (or the fixed-effect approach when panel data are used). The reduced-form residuals share the same properties as the endogenous variables. Thus Rigobon (2003) suggests computing covariance matrices in two subsamples defined by heteroskedasticity in the structural shocks and using these matrices in the GMM estimation of the contemporaneous coefficients.

2.2 Data Description

The dataset used in this study is taken from the World Development Indicators of World Bank (2008) and consists of 158 countries over the 1960-2007 period. Following common practice, the data are averaged over non-overlapping subperiods: 1960-1965, 1966-1970, 1971-1975, … , 2001-2007.[12] This gives up to 9 cross-sections per country. And we also use data covering the 1980-2007 period which is characterized as relatively moderate economic fluctuations, to check whether the relationship between growth and volatility differs with time periods considered. Economic growth (*growth*) is measured as the average growth rate of real GDP per capita over the non-overlapping subperiods.

Growth volatility (*volatility*) is measured by the standard deviation of annual growth rates of real GDP per capita over the subperiods. Conventionally, the volatility in the cross-section or time-series studies is measured by the (moving) standard deviation of a variable. However, the limitation of this measure lies in its inability to distinguish between variability and uncertainty. It includes the variance of both

[12] The use of averages rather than annual data is to abstract from business cycles and to focus on the long-run link between growth and volatility. Averaging is also likely to lessen the impact of measurement errors and simplifies the specification of dynamics of the model.

expected and unexpected components of a variable, even though the former does not imply any uncertainty. Since introduction of the ARCH approach, the prevalent measure of uncertainty has been the conditional standard deviation and variance. Specifically, GARCH-type techniques estimate a model of the variance of unpredictable innovations in a process. As argued, such a time-varying residual standard deviation or variance is better to capture uncertainty. Although uncertainty is usually of primary interest, there are at least two good reasons for focusing on volatility rather than uncertainty, as pointed by Malik and Temple (2008). First, some costs of output variation will be incurred even if the variation is anticipated, especially when the possibility of consumption smoothing and other behavioral responses is limited by market incompleteness and credit constraints. Second, the measurement of uncertainty relies on a specific forecasting model, usually a simple autoregressive model. Moreover, given that annual growth rates are not strongly autocorrelated, the two approaches are unlikely to differ greatly. As a robustness check, we also use the conditional standard deviations (*uncertainty*) derived from a GARCH model to proxy for growth uncertainty.

To further strengthen our results, we include alternative conditioning information sets. First, the simple conditioning set includes the initial GDP per capita (*igdp*) to capture (conditional) convergence, the investment to GDP ratio (*inv*), and the rate of population growth (*popg*) as a proxy for the rate of labor growth. Second, the policy conditioning set includes the simple set plus the ratio of government consumption to GDP (*gov*) as well as inflation rate (*inf*) to control for macroeconomic instability. Third, the full conditioning set further adds an openness index (*trade*) defined as the ratio of trade volume over GDP and financial development (*privo*) measured by bank credits to the private sector as a share of GDP. In addition, each conditioning set includes period dummies to control for time-varying factors and country-specific dummies to capture the effect of structural variables which do not change (significantly) over time. All control variables are in natural logarithm except for population growth and dummies. The list of sample countries and descriptive statistic summary are provided in Tables A1 and A2 in Appendix, respectively.

3 Empirical Results

3.1 Main Results

For identification of simultaneous-equation models, this paper employs the IH methodology. Applying the procedure suggested in Rigobon (2003), we first run the reduced-form *growth* and *volatility* regressions in (4) using the fixed-effect panel data approach and store the residuals.[13] The residuals share the same contemporaneous properties as the structural variables. We then compute the unconditional covariance matrix for each country and split the data into four distinct groups: high-low standard deviation groups of economic growth and the volatility. Following Lee, Ricci and Rigobon (2004), countries are grouped according to the median values. Finally, the covariance matrices are used to estimate the contemporaneous parameters through GMM.

The IH fixed-effect estimation results for the 1960-2007 period are summarized in Table 1. The overall message across alternative volatility measures and conditioning sets is that countries with higher volatility tend to experience lower economic growth, while countries with faster economic growth appear to confront greater volatility. For comparison, the results using OLS fixed- and random-effect techniques are reported in Tables A3 and A4 of Appendix.

[13] The validity of IH methodology relies on heteroskedasticity in the structural variances. To avoid the heteroskedasticity arising from model specifications or omitted variables bias, we employ the estimator of panel fixed effect to control for time-invariant and other country-specific unobserved effects to minimize the possibility.

First, when growth volatility is measured by the realized standard deviations as shown in Panel A of Table 1, volatility enters the growth equation negatively and highly significantly, implying that volatility is detrimental to growth. The negative growth effect of volatility is economically significant as well. A one-standard deviation increase in growth volatility is associated with a decline in output growth in the range of 0.68-0.33 percent, depending upon the coefficient estimate used. By contrast, growth enters the volatility equation in a positive and significant way, implying that economic growth produces more volatility in output growth. However, the effect of growth on volatility turns out economically small. A one percent increase in output growth would cause output volatility to boost only by 0.06-0.01 standard deviation. The finding of coexistence of negative growth effect of volatility and positive volatility effect of growth appears insensitive to alternative model specifications.

Next, regarding the correlation between growth and uncertainty, an unexpected component of volatility, Panel B of Table 1 shows quite similar results. Across alternative conditioning sets, growth uncertainty has a highly significant and negative impact on output growth whereas growth affects uncertainty in a strongly significant and positive way. And the magnitude of the effect of volatility on growth is larger than that of the volatility effect of growth. Note that the effect of volatility on growth appears to be larger than that of uncertainty on growth. The evidence seems to accord with the argument that both anticipated and unanticipated components of volatility would incur costs that have negative impacts on economic growth.

As a further robustness check, we also experiment with the IH random effect estimation. Table 2 summarizes the results and continues to find a negative effect of volatility (uncertainty) on growth and a positive impact of growth on volatility (uncertainty), across alternative conditioning information sets. Table 2 overall shows qualitatively same results as Table 1 does.

Furthermore, we check whether the growth-volatility link is sensitive to the time period. It is well recognized that since 1980, a number of emerging markets and transition countries began to undertake trade and financial liberalization programs around this period; the dramatic surge in international financial flows across industrial countries as well as between industrial and developing countries got started; and the Great Moderation (the decline in business cycle volatility across all groups of countries, especially the industrial ones) began. In light of these facts, there may exist potential structural breaks in the link between growth and volatility. This paper explores this possibility and reports the IH fixed- and random-effect estimation results for the 1980-2007 period in Table 3 and 4.

Once again, the finding of negative growth effect of volatility and positive volatility impact of growth still holds, irrespective of alternative model specifications and econometric methods. The only exception is that the volatility effect of growth is significantly negative when applying the random effect estimation and using the simple conditioning set in Table 4. In addition, we find that growth uncertainty has much larger impact on economic growth than growth volatility does, suggesting that in this period, unanticipated component of growth volatility is more relevant in explaining the negative response of economic growth.

Our evidence of significant and negative growth effect of volatility confirms the finding of Ramey and Ramey (1995) and supports the hypothesis of irreversibility in investment and optimal waiting. It is also possible that greater uncertainty about the future reinforces capital market imperfection and hence prevents physical and human capital accumulation.[14] On the other hand, the finding of significant and positive impact of growth on volatility suggests that there exists feedbacks from growth to

[14] See Hubbard (1998) for detailed discussion on how capital market imperfections affect investment.

volatility and hence a failure to account for the endogeneity would result in biased conclusions. As a whole, our results point to the dynamic instability of stabilization policy in reducing economic fluctuations and hence improving growth as it would result in an unintended rise in output volatility.

3.2 Subsample Investigations

This section explores whether the interaction between economic growth and growth volatility varies with economic and financial conditions. It checks on nonlinearity in the interrelationship. The IH fixed-effect estimation results are reported in Table 5.[15] On balance, we find that across subsamples, output volatility indeed hinders economic growth after considering the reverse influence of growth on volatility. The data indeed reveal evidence for potential nonlinearity in the volatility-growth nexus.

First, we examine the effect of economic development on the volatility-growth nexus. As argued in Acemoglu and Zilibotti (1997), lower levels of economic development, by constraining the ability to diversify sector-specific risks, might lead to both higher volatility and lower growth. In other words, the negative relationship between growth and volatility might be more obvious in less developed countries. Our results in Panel A of Table 5 where countries are split into high-, medium- and low-income subsamples according to their initial income level indicate that a highly significant and negative growth effect of volatility coexists with a significant positive volatility impact of growth. An exception is the low-income group in which the positive effect of growth on volatility is not statistically significant. The evidence confirms our previous conclusions that growth volatility is detrimental to economic

[15] To save space, we only report the results using the full conditioning set for the 1960-2007 period. The results from alternative model specifications and for the 1980-2007 are available upon request.

growth, even after controlling for the feedback from growth to volatility. Moreover, it shows that the respective effects of volatility and growth are stronger and more significant for the medium-income group.

Next, Panel B checks the effect of financial development on the growth-volatility relationship. Countries are divided into high-, medium- and low-financial-development groups according to the initial value of financial development measure. A highly significant and negative growth effect of volatility continues to be found for all country groups, while the significant feedback effect of growth on volatility vary with the level of financial development. And the negative growth effect of volatility seems to be largest in countries with medium degrees of financial development and lowest in countries with high financial development. The relatively large negative effects in countries with lower financial development is in line with Aghion *et al*. (2005), which to the extent that liquidity risk increases with aggregate volatility, volatility discourages long-term investment and slows down output growth, and the more so the tighter the credit constraints.

Panel C reports the results concerning whether the degree of trade openness affects the nexus between growth and volatility. We find a transition among the groups of countries with different trade openness. In countries with low and medium degrees of trade openness, both respective effects of volatility and growth are significant and negative. In high-openness countries, however, both of the effects turn significantly positive. Hence, the evidence indicates that, after considering the reverse causality, the influence of volatility on growth is negative for lower-openness countries and turns positive for countries with high levels of trade openness. It is consistent with Kose, Prasad and Terrones (2006), who find that trade openness has weakened the negative linkage between growth and volatility, implying that countries that are less open to trade flows may face a severe trade-off between growth and volatility.

Finally, Panel D checks whether the growth-volatility link varies with the level of inflation. Countries are split into high-, medium- and low-inflation regimes according to their initial level of inflation. We find that our main results remain intact. The growth effect of volatility is significant and negative while the volatility effect of growth is significantly positive, across all subsamples. And the data reveal that volatility has largest impacts on growth in high-inflation countries. It implies that inflation not only strengthens the negative effects of inflation on growth (Fischer, 1993; Barro, 1995; Bruno and Easterly, 1998), but also reinforces the negative impact of growth volatility on growth.

The results with the IH random-effect estimation for the same considerations as in Table 5 are summarized in Table 6. It in general shows results similar to those in Table 5. There very likely exist two-way interactions between growth and its volatility. And, while the volatility effect of growth varies across alternative subsamples, growth volatility appears to have adverse influence on economic growth.

4 Conclusions

The theoretical and empirical literature on the interrelationship between economic growth and growth volatility has not reached a consensus. The inconsistency among existing empirical studies is attributed to the simultaneity and joint determination biases. Average growth and its variability are two moments of the same underlying income process, and are likely to be jointly determined. Furthermore, because of feedback from volatility to growth and because mean growth and its variability have common underlying determinants, it is essential that one estimate a two-equation system to jointly explain both mean growth and volatility in growth. This paper revisits this issue and examines the growth-volatility nexus by applying the IH methodology of Rigobon (2003) to solve the identification problem of simultaneous equations model.

Based on a panel of 158 countries covering the period 1960-2007, our empirical result shows that growth volatility has a negative effect on economic growth after accounting for positive reverse causation from growth to volatility. The results are fairly consistent across alternative sets of conditioning variables, econometric methods, and time periods. The negative impact of growth on volatility thus confirms that more stable economies are more likely to grow faster, meaning that stabilization policy that mitigates business fluctuations would lead to higher economic growth. And the positive feedback of growth to volatility further suggests the need for continual stabilization efforts to maintain both growth and stability of the economy.

Reflecting nonlinearity in the growth-volatility nexus suggested in the literature, this study takes a step further and investigates whether the relationship varies with economic and financial conditions. The results considering different levels of economic and financial development, trade openness, and inflation provide suggestive evidence of nonlinearity in the nexus. It is noted that this paper does not formally and rigorously investigate the issue of nonlinearity. Since such an empirical assessment approximates specific conditions under which volatility hinders or stimulates growth, further study on the potential nonlinearity is needed to gain whole picture of the interrelationship between growth and volatility.

References

Acemoglu, D. and Johnson, S. (2005). Unbundling Institutions. *Journal of Political Economy* 113(5), 949-995.

Acemoglu, D., Johnson, S., Robinson, J. and Thaicharoen, Y. (2003). Institutional Causes, Macroeconomic Symptoms: Volatility, Crises and Growth. *Journal of Monetary Economics* 50, 49-123.

Acemoglu, D., Robinson, J. A. and Johnson, S. (2001). The Colonial Origins of Comparative Development: An Empirical Investigation. *American Economic Review* 91, 1369-1401.

Acemoglu, D. and Zilibotti, F. (1997). Was Prometheus Unbound by Chance? Risk, Diversification, and Growth. *Journal of Political Economy* 105, 709-751.

Aghion, P., Banerjee, A. V., Angeletos, G.-M. and Manova, K. (2005). Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment. *NBER Working Paper* No. W11349.

Aghion, P., Banerjee, A.V. and Piketty, T. (1999). Dualism and Macroeconomic Volatility. *Quarterly Journal of Economics* 114(4), 1359-1397.

Aizenman, J. and Marion, N. (1993). "Policy Uncertainty, Persistence and Growth." *Review of International Economics* 1, 145-163.

Aizenman, J. and Marion, N. (1999). Volatility and Investment: Interpreting Evidence from Developing Countries. *Economica* 66, 157-179.

Barro, R. J. (1995). Inflation and Economic Growth. *Bank of England Quarterly Bulletin*, 166-176.

Bhattacharyya, S. (2009). Unbundled Institutions, Human Capital and Growth. *Journal of Comparative Economics* 37(1), 106-120.

Black, F. (1987). *Business Cycles and Equilibrium*. New York: Blackwell.

Blackburn, K. (1999). Can Stabilisation Policy Reduce Long-Run Growth? *Economic Journal* 109(452), 67-77.

Blackburn, K. and Pelloni, A. (2005). Growth, Cycles, and Stabilization Policy. *Oxford Economic Papers* 57, 262-282.

Bohl, M. T., P. L. Siklos and T. Werner. 2007. Do central banks react to the stock market? The case of the Bundesbank. *Journal of Banking and Finance* 31: 719-733.

Bose, N. and Murshid, A. P. (2008). Mitigating the Growth-Effects of Inflation through Financial Development. *The B.E. Journal of Macroeconomics* 8 (1), Article 8.

Bound, J., Jaeger, D. A. and Baker, R. M. (1995). Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak. *Journal of the American Statistical Association* 90, 443-450.

Bredin, D., Elder, J. and Fountas, S. (2009). Macroeconomic Uncertainty and Performance in Asian countries. *Review of Development Economics* 13(2), 215-229.

Bruno, M. and Easterly, W. (1998). Inflation Crises and Long-Run Growth. *Journal of Monetary Economics* 41, 3-26.

Bullard, J. B. and Keating, J. W. (1995). The Long-Run Relationship between Inflation and Output in Postwar Economies. *Journal of Monetary Economics* 36, 477-496.

Caporale, G. M., Cipollini, A. and Demetriades, P. O. (2005). Monetary policy and the exchange rate during the Asian crisis: Identification through heteroskedasticity. *Journal of International Money and Finance* 24, 39-53.

Caporale, T. and McKiernan, B. (1998). The Fischer Black Hypothesis: Some Time-Series Evidence. *Southern Economic Journal* 64, 765-771.

Chong, A. and Gradstein, M. (2009). Volatility and Firm Growth. Journal of Economic Growth 14, 1-25.

Edwards, J.A. and Thames, F.C. (2009). The Effects of Economic and Political Development on GDP Growth Volatility. *Global Economy Journal* 9(2), Article 1. doi**:** 10.2202/1524-5861.1452.

Easterly, W. (2005). National Policies and Economic Growth. In P. Aghion and S. Durlauf (EDs.), Handbook of Economic Growth. Elsevier.

Easterly, W. and Levine, R. (2003). Tropics, Germs, and Crops: The Role of Endowment in Economic Development. *Journal of Monetary Economics* 50(1), 3-39.

Fatas, A. (2002). The Effects of Business Cycles on Growth. In N. Loayza and R. Soto, eds., *Economic Growth: Sources, Trends and Cycles*. Santiago: Central Bank of Chile.

Fatas, A. and Mihov, I. (2006). Policy Volatility, Institutions and Economic Growth. *CEPR Discussion Paper* No. 5388.

Fischer, S. (1993). The Role of Macroeconomic Factors in Growth. *Journal of Monetary Economics* 32, 485-511.

Fountas, S. and Karanasos, M. (2006). The Relationship between Economic Growth and Real Uncertainty in the G3. *Economic Modelling* 23, 638-647.

Fountas, S., Karanasos, M. and Kim, J. (2002). Inflation and Output Growth Uncertainty and Their Relationship with Inflation and Output Growth. *Economics Letters* 75, 293-301.

Fountas, S., Karanasos, M. and Kim, J. (2006). Inflation Uncertainty, Output Growth Uncertainty and Macroeconomic Performance. *Oxford Bulletin of Economics and Statistics* 68, 319-343.

Gillman, M. (2005). Contrasting Models of the Effect of Inflation on Growth. *Journal of Economic Surveys* 19, 113-136.

Grier, K. B., Henry, O. T., Olekalns, N. and Shields, K. (2004). The Asymmetric Effects of Uncertainty on Inflation and Output Growth. *Journal of Applied Econometrics* 19, 551-565.

Grier, K. B. and Perry, M. J. (2000). The Effects of Real and Nominal Uncertainty on Inflation and Output Growth: Some GARCH-M Evidence. *Journal of Applied Econometrics 1*5, 45-58.

Grier, K. B. and Tullock, G. (1989). An Empirical Analysis of Cross-national Economic Growth, 1951-1980. *Journal of Monetary Economics* 24(2), 259-276.

Hall, R. E. and Jones, C. I. (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics* 114, 83-116.

Henry, O. and Olekalns, N. (2000). The Effects of Recessions on the Relationship between Output Variability and Growth. *Southern Economic Journal* 68, 683-692.

Hnatkovska, V. and Loayza, N. (2005). Volatility and Growth. In J. Aizenman and B. Pinto, eds., *Managing Economic Volatility and Crises: A Practitioner's Guide*. Cambridge: Cambridge University Press.

Hopenhayn, H. A. and Muniagurria, M. E. (1996). "Policy Volatility and Economic Growth." *Review of Economic Studies* 63.

Hubbard, R. G. (1998). Capital-Market Imperfections and Investment. *Journal of Economic Literature* 36, 193-225.

Imbs, J. (2007). Growth and Volatility. Journal of Monetary Economics 54, 1848-1862.

Khan, M. S. and Senhadji, A. S. (2001). Threshold Effects in the Relationship between Inflation and Growth. *IMF Staff Papers* 48, 1-21.

Knack, S and Keefer, P. (1995). Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures. *Economics and Politics* 7(3), 207-227.

Kormendi, R. C. and Meguire, P. (1985). Macroeconomic Determinants of Growth: Cross-country Evidence. *Journal of Monetary Economics* 16(2), 141-163.

Kose, M. A., Prasad, E. S. and Terrones, M. E. (2006). How Do Trade and Financial

Integration Affect the Relationship between Growth and Volatility? *Journal of International Economics* 69, 176-202.

Lee, H. Y., Ricci, L. A. and Rigobon, R. (2004). Once again, is openness good for growth? *Journal of Development Economics* 75, 451-472.

Levine R. (1997). Financial development and economic growth: Views and agenda. *Journal of Economic Literature* 35, 688-726.

Levine, R. (2005). Finance and growth: Theory and evidence. In P. Aghion and S. N. Durlauf, eds., *Handbook of Economic Growth*. Amsterdam: Elsevier.

Malik, A. and Temple, J. R. W. (2008). The Geography of Output Volatility. *Journal of Development Economics*, doi:10.1016/j/jdeveco.2008.10.003.

Martin, P. and Rogers, C. A. (2000). Long-Term Growth and Short-Term Economic Instability. *European Economic Review* 44(2), 359-381.

Mirman, L. J. (1971). Uncertainty and Optimal Consumption Decisions. *Econometric*a 39(1), 179-185.

Pindyck, R. S. (1991). Irreversibility, Uncertainty, and Investment. *Journal of Economic Literature* 29(3), 1110-1148.

Rafferty, M. (2005). The Effects of Expected and Unexpected Volatility on Long-Run Growth: Evidence from 18 Developed Economies. *Southern Economic Journal* 71, 582-591.

Ramey, G. and Ramey, V. A. (1991). Technology Commitment and the Cost of Economic Fluctuations. *NBER Working Paper* No. 3755.

Ramey, G. and Ramey, V. A. (1995). Cross-Country Evidence on the Link between Volatility and Growth. *American Economic Review* 85, 1138-1151.

Rigobon, R. (2003). Identification through heteroskedasticity. *Review of Economics and Statistics* 85, 777-792.

Rigobon, R. and Rodrik, D. (2005). Rule of law, democracy, openness, and income: Estimating the interrelationships. *Economics of Transition* 13, 533-564

Rigobon, R. and Sack, B. (2003). Measuring the reaction of monetary policy to the stock market. *Quarterly Journal of Economics* 118, 639-669.

Rodrik, D., Subramanian, A. and Trebbi, F. (2004). Institutions rule: The primacy of institutions over geography and integration in economic development. *Journal of Economic Growth* 9, 131-165.

Speight, A. (1999). UK Output Variability and Growth: Some Further Evidence. *Scottish Journal of Political Economy* 46, 175-184.

Table 1: IH Fixed-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0126*** (0.0012)		0.0064*** (0.0014)		0.0027** (0.0014)
volatility	-0.8398*** (0.0213)		-0.5163*** (0.0235)		-0.4148*** (0.0240)	
Obs.	1056		941		929	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0089*** (0.0011)		0.0123*** (0.0018)		0.0176*** (0.0017)
uncertainty	-0.2710*** (0.0192)		-0.1237*** (0.0251)		-0.1833*** (0.0248)	
Obs.	1052		935		923	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 2: IH Random-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0166*** (0.0012)		0.0058*** (0.0014)		0.0028** (0.0013)
volatility	-0.9794*** (0.0213)		-0.5444*** (0.0229)		-0.4432*** (0.0222)	
Obs.	1056		941		929	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0115*** (0.0011)		0.0165*** (0.0015)		0.0184*** (0.0014)
uncertainty	-0.4586*** (0.0198)		-0.4021*** (0.0236)		-0.4117*** (0.0229)	
Obs.	1052		935		923	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 3: IH Fixed-Effect Estimates of Growth and Volatility (1980-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0063*** (0.0014)		0.0120*** (0.0022)		0.0096*** (0.0023)
volatility	-0.7532*** (0.0227)		-0.6510*** (0.0291)		-0.6126*** (0.0315)	
Obs.	724		674		668	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0247*** (0.0016)		0.0475*** (0.0028)		0.0511*** (0.0028)
uncertainty	-0.8941*** (0.0285)		-0.9901*** (0.0407)		-1.0466*** (0.0422)	
Obs.	723		671		665	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 4: IH Random-Effect Estimates of Growth and Volatility (1980-2007)

Panel A: Growth volatility

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		-0.0047*** (0.0012)		0.0131*** (0.0022)		0.0108*** (0.0022)
volatility	-0.6159*** (0.0243)		-0.6951*** (0.0317)		-0.6780*** (0.0318)	
Obs.	724		674		668	

Panel B: Growth uncertainty

	growth	*uncertainty*	*growth*	*uncertainty*	*growth*	*uncertainty*
growth		0.0153*** (0.0013)		0.0324*** (0.0023)		0.0343*** (0.0022)
uncertainty	-1.1155*** (0.0287)		-1.0600*** (0.0418)		-1.1293*** (0.0423)	
Obs.	723		671		665	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table 5: IH Fixed-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Economic Development

	Low-income		*Mid-Income*		*High-Income*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0019 (0.0109)		0.0763*** (0.0043)		0.0113* (0.0070)
volatility	-0.3540*** (0.1343)		-1.6023*** (0.0799)		-0.2525*** (0.0648)	
Obs.	284		314		331	

Panel B: Financial Development

	Low-financial-development		*Mid-financial development*		*High-financial development*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0343*** (0.0049)		-0.0287*** (0.0112)		0.0247*** (0.0103)
volatility	-0.2890*** (0.1040)		-0.5285*** (0.1681)		-0.2037*** (0.0756)	
Obs.	264		334		331	

Panel C: Trade Openness

	Low-trade-openness		*Mid-trade-openness*		*High-trade-openness*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0355*** (0.0057)		-0.0062* (0.0040)		0.0172*** (0.0042)
volatility	-0.2478*** (0.0633)		-0.2655*** (0.0663)		0.2827*** (0.0623)	
Obs.	359		321		249	

Panel D: Inflation

	Low-inflation		Mid-inflation		High-inflation	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0599*** (0.0030)		0.0136** (0.0073)		0.0199*** (0.0056)
volatility	-0.6332*** (0.0536)		-0.1183* (0.0815)		-1.1678*** (0.1014)	
Obs.	302		354		273	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured by the standard deviation of output growth (*volatility*). The full conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), the rate of population growth (*popg*), government expenditure as a share of GDP (*gov*), inflation rate (*inf*), trade openness (*trade*) and financial development (*privo*) indicators, and period- and country-dummies. The standard errors are in parentheses. ***, **, and * denotes significant at 1 %, 5%, and 10% level, respectively.

Table 6: IH Random-Effect Estimates of Growth and Volatility (1960-2007)

Panel A: Economic Development

	Low-income		*Mid-Income*		*High-Income*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0041 (0.0071)		0.0737*** (0.0064)		0.0085** (0.0051)
volatility	-0.3823*** (0.0825)		-1.8384*** (0.1066)		-0.2134*** (0.0613)	
Obs.	284		314		331	

Panel B: Financial Development

	Low-financial-development		*Mid-financial development*		*High-financial development*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0339*** (0.0040)		0.0107* (0.0079)		0.0018 (0.0095)
volatility	-0.4434*** (0.0859)		-1.0523*** (0.1191)		-0.0626 (0.0695)	
Obs.	264		334		331	

Panel C: Trade Openness

	Low-trade-openness		*Mid-trade-openness*		*High-trade-openness*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0279*** (0.0044)		-0.0049 (0.0042)		-0.0089** (0.0039)
volatility	-0.2555*** (0.0532)		-0.3620*** (0.0655)		0.5450*** (0.0591)	
Obs.	359		321		249	

Panel D: Inflation

	Low-inflation		Mid-inflation		High-inflation	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		0.0319*** (0.0027)		0.0257*** (0.0066)		0.0058 (0.0048)
volatility	-0.3393*** (0.0470)		-0.3018*** (0.0799)		-1.0990*** (0.0941)	
Obs.	302		354		273	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured by the standard deviation of output growth (*volatility*). The full conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), the rate of population growth (*popg*), government expenditure as a share of GDP (*gov*), inflation rate (*inf*), trade openness (*trade*) and financial development (*privo*) indicators, and period- and country-dummies. The standard errors are in parentheses. ***, **, and * denotes significant at 1 %, 5%, and 10% level, respectively.

Appendix

Table A1: A List of Sample Countries

AGO	COL	HRV	MEX	SGP
ALB	CPV	HTI	MKD	SLE
ARG	CRI	HUN	MLI	SLV
ARM	CYP	IDN	MNG	SUR
AUS	CZE	IND	MOZ	SVK
AUT	DEU	IRL	MRT	SVN
AZE	DMA	IRN	MUS	SWE
BDI	DNK	ISL	MWI	SWZ
BEL	DOM	ISR	MYS	SYC
BEN	DZA	ITA	NER	SYR
BFA	ECU	JAM	NGA	TCD
BGD	EGY	JOR	NIC	TGO
BGR	ESP	JPN	NLD	THA
BHR	EST	KAZ	NOR	TON
BHS	ETH	KEN	NPL	TTO
BLR	FIN	KGZ	NZL	TUN
BLZ	FJI	KNA	OMN	TUR
BOL	FRA	KOR	PAK	UGA
BRA	GAB	KWT	PAN	UKR
BRB	GBR	LAO	PER	URY
BRN	GEO	LBN	PHL	USA
BTN	GHA	LCA	PNG	VCT
BWA	GMB	LKA	POL	VEN
CAF	GNB	LSO	PRT	VNM
CAN	GNQ	LTU	PRY	VUT
CHE	GRC	LUX	ROM	YEM
CHL	GRD	LVA	RUS	ZAF
CHN	GTM	MAC	RWA	ZAR
CIV	GUY	MAR	SAU	ZMB
CMR	HKG	MDA	SDN	ZWE
COG	HND	MDG	SEN	
AGO	COL	HRV	MEX	

Table A2: Descriptive statistics (1960-2007)

Panel A: Summary Statistics

	growth	*volatility*	*uncertainty*	*igdp*	*inv*	*popg*	*trade*	*gov*	*inf*	*privo*
Mean	3.8413	1.0312	2.5434	7.4739	3.0183	1.7597	4.1065	2.6646	0.1575	3.2138
Median	3.8326	1.0465	2.5607	7.3601	3.0504	1.9124	4.1303	2.6788	0.0700	3.2345
Std.	3.8987	0.8055	1.1922	1.5353	0.3522	1.8001	0.6033	0.3958	0.3635	0.9415
Max.	38.5745	3.8873	7.6639	10.9884	4.4194	10.5462	6.0342	4.0325	4.1922	5.3980
Min.	-20.6200	-4.8493	-1.3919	4.3524	1.1581	-44.4084	1.6704	1.2578	-0.0435	-0.0033
Obs.	1178	1171	1170	1205	1089	1386	1163	1168	1062	1115

Panel B: Correlation

growth	1.0000									
volatility	-0.0676	1.0000								
uncertainty	0.0022	0.6717	1.0000							
igdp	-0.0584	-0.2463	-0.3476	1.0000						
inv	0.3150	-0.1126	-0.1072	0.3294	1.0000					
popg	0.0608	0.0688	0.1150	-0.3230	-0.1353	1.0000				
trade	0.0554	0.0318	0.0556	0.2147	0.3670	-0.1414	1.0000			
gov	-0.1387	0.0165	-0.0148	0.3714	0.2040	-0.2157	0.3827	1.0000		
inf	-0.3865	0.2059	0.1511	-0.1031	-0.1234	-0.0347	-0.0848	-0.0237	1.0000	
privo	0.0032	-0.3280	-0.3800	0.7126	0.3788	-0.2207	0.2236	0.3226	-0.2220	1.0000

Table A3: OLS Fixed-Effect Estimates of Growth and Volatility (1960-2007)

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0154**		-0.0139*		-0.0137
		(0.0069)		(0.0084)		(0.0085)
volatility	-0.3618**		-0.2537*		-0.2504	
	(0.1618)		(0.1535)		(0.1549)	
constant	14.9873***	1.9920***	24.2826***	0.5969	26.2618***	0.8254
	(2.9868)	(0.6221)	(3.6377)	(0.8753)	(3.7223)	(0.8982)
igdp	-3.2693***	-0.0087	-4.0084***	0.0426	-4.0788***	0.0663
	(0.3979)	(0.0853)	(0.4312)	(0.1064)	(0.4520)	(0.1112)
inv	4.8469***	-0.1998**	3.7490***	-0.2678**	3.8128***	-0.2486**
	(0.4384)	(0.0963)	(0.4527)	(0.1101)	(0.4619)	(0.1124)
popg	-0.0988	-0.0308**	-0.1823***	-0.0276**	-0.1835***	-0.0264**
	(0.0618)	(0.0127)	(0.0565)	(0.0133)	(0.0566)	(0.0133)
trade			1.7135***	0.3400***	1.7725***	0.3550***
			(0.5141)	(0.1206)	(0.5159)	(0.1209)
gov			-2.7730***	-0.0456	-2.8179***	-0.0217
			(0.5082)	(0.1212)	(0.5244)	(0.1250)
inf			-3.6233***	0.1714**	-3.6080***	0.1667**
			(0.3255)	(0.0818)	(0.3287)	(0.0825)
privo					-0.2336	-0.0782
					(0.2512)	(0.0587)
Obs	1056		941		929	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. To save space, the estimates for dummies are not reported but available upon request. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

Table A4: OLS Random-Effects Estimates of Growth and Volatility (1960-2007)

	simple		*policy*		*full*	
	growth	*volatility*	*growth*	*volatility*	*growth*	*volatility*
growth		-0.0145**		-0.0095		-0.0096
		(0.0064)		(0.0075)		(0.0075)
volatility	-0.2860*		-0.1249		-0.1518	
	(0.1480)		(0.1422)		(0.1450)	
constant	-3.3549***	2.4824***	0.8106	1.4264***	1.9047***	1.9395***
	(1.2399)	(0.2677)	(1.4019)	(0.3472)	(1.5491)	(0.3651)
igdp	-0.4750***	-0.1215***	-0.5126***	-0.1374***	-0.3875***	-0.0721**
	(0.0955)	(0.0238)	(0.0975)	(0.0254)	(0.1229)	(0.0302)
inv	4.3025***	-0.1061	3.9407***	-0.2132**	4.0442	-0.1487
	(0.3577)	(0.0824)	(0.3635)	(0.0914)	(0.3717)	(0.0919)
popg	0.0379	-0.0221*	-0.0813	-0.0199	-0.0834	-0.0167
	(0.0590)	(0.0120)	(0.0545)	(0.0125)	(0.0548)	(0.0124)
trade			0.3895	0.3175***	0.4261***	0.3044***
			(0.2559)	(0.0648)	(0.2593)	(0.0628)
gov			-1.6188***	0.0838	-1.6165***	0.1188
			(0.3546)	(0.0878)	(0.3607)	(0.0867)
inf			-3.4537***	0.2692***	-3.5256***	0.2322***
			(0.2982)	(0.0730)	(0.3046)	(0.0739)
privo					-0.3128*	-0.1655***
					(0.1875)	(0.0439)
Obs	1056		941		929	

Note: Economic growth is measured by the growth rate of per-capita real GDP (*growth*). Growth volatility is measured either by the standard deviation of output growth (*volatility*) or by the conditional standard deviation of output growth (*uncertainty*). The simple conditioning information set includes the initial real GDP per capita (*igdp*), the investment to GDP ratio (*inv*), and the rate of population growth (*popg*). The policy conditioning set is the simple set plus government expenditure as a share of GDP (*gov*) and inflation (*inf*). And the full conditioning set adds trade openness (*trade*) and financial development (*privo*) indicators to the policy set. All conditioning sets also include 5-year period dummy and country-specific dummy. To save space, the estimates for dummies are not reported but available upon request. The standard errors are in parentheses, and ***, **, and * indicates statistical significance at 1 %, 5% and 10% level, respectively.

經濟成長與其不確定性之關聯探討

摘要

本文旨在利用聯立方程式(simultaneous equations system)檢定經濟成長與其不確定性之關聯。利用變異數異質性的認定法(the identification through Heteroskedasticity method of Rigobon (2003))於包括 158 國橫跨 1960-2007 年之縱橫資料進行分析。我們發現經濟成長不確定性不利於經濟成長，意味穩定政策不只緩和短期經濟波動同時有利於長期經濟成長。我們同時發現經濟成長家數經濟成長不確定性，支持存在回饋現象(the feedback effects from growth to the volatility)之論點。此外當將資料根據國家特色區分成不同之樣本，儘管經濟成長對不確定性的影響不確定但我們持續發現經濟成長不確定性不利於經濟成長，

關鍵字: 經濟成長，經濟成長不確定性，聯立方程式，變異數異質性的認定法

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

97 年 7月13日

附件三

報告人姓名	金東炫	服務機構及職稱	靜宜大學財金系助理教授
時間 會議地點	*Western Economic Association International* 84th Annual Conference June 29–July 3, 2009 Vancouver, Canada	本會核定補助文號	NSC97-2410-H-032-003
會議名稱	(中文)西方經濟學會國際第 84 屆年會 (英文)WEAI 84th Annual Conference		
發表論文題目	(中文) Economic Growth and Growth Volatility Revisited (英文) 經濟成長與其波動性之研究分析		

參加年會心得報告　（共同主持人:靜宜金融系金東炫）

一、 會議進行日期、地點與主題

日期: 2009 年 6 月 29 日 至 7 月 3 日

地點: 溫哥華

會議主題: 經濟相關議題

二　參加會議經過

由於一直訂不到台北直飛溫哥華的机位，所以錯失了前兩天的會議。

The WEAI 84th Annual Conference consists of many subjects of different doctrines in economics such as . There were total 25 sections including one section for doctoral students in the conference. And for each section there are 3-4 papers presented. Each presenter has 10 minutes per person for presentation and questions. Finally, presenters are from different countries such as Taiwan, Thailand, Korea, the US, Australia, Singapore, and so on.

三　與會心得

又是一年一度的大拜拜。由WEAI所主辦並有來自世界各國重要經濟學會贊助的第84屆會議熱鬧非凡，這個經濟學界的盛事，似乎一點也沒受到Swine Flu的影響，儘管有些場次與報告被迫減少。身為WEAI會員之一，我很榮幸有機會參與並分享自己的研究心得。雖然無法從section discussion中獲取有用之information to improve our research. However, in other sections, I did get a lot of knowledge which is very helpful to improve our current paper and for the future study. Especially, my recent research interest focuses on macro-finance such as the link between/among financial development, financial openness, trade openness, and growth. There are some topic are very useful to improve my research. For example, “Foreign capital flows and growth in the short run and in the long run” presented by Chung, “Globalization versus deglobalization of developing countries” by Karunaratne, “Sudden stops and currency crises” by Schreyer, et al., “Sudden stops” by Ratanamaneichat and Schreyer, “Financial integration in East Asia: Evidence from stock prices” by Kim, and “Monetary policy strategy in a global environment” by Vitale, among others.

Moreover, the topics presented in the conference were very diverse such that we could get some senses about other fields but, at the same time, we also suffered from lack of enough knowledge about other doctrines. Of course, because most people are from different countries with different backgrounds, it is quite bothering but interesting to discuss and communicate with them. As you know, even though with the same field, people don’t easily agree with one another. Anyway, it is a really good experience.

四　建議

由於參加國際性會議有助於擴展國際視野，並增進台灣國際名聲，因此除期許自多參與國際性會議外，也感謝國科會的補助以順利完成此次的行程。有鑒於此次的發表獲得多國外學者的支持，因此建議政府可以利用穩定之政策同時達成短期經濟穩定與長期經濟成長之目標。

由於此次會議並未要求發表者應準備多份論文影本，大會也未準備，所以讓此次會議失分不少，畢竟有書面資料可幫助了解與吸收。

五　攜回資料名稱及內容

84th WEAI 年會資料與少數報告。