



# Revisiting the link between output growth and volatility: panel GARCH analysis

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## Abstract

This paper explores the link between output growth and volatility using several macroeconomic variables for a panel of countries for the period of 1971–2014. Using an augmented panel GARCH-M model, we allow for the first time in the literature for independent variables to be part of the conditional equations. The paper is also novel in terms of encompassing an extensive number of countries and country groups. The relationship between output growth and volatility is observed to vary between different country groups. Empirical findings regarding the effect of exogenous variables suggest that trade openness contributes to economic growth and institutional quality lowers economic volatility.

**Keywords** Growth · Volatility · Panel GARCH-M model

## 1 Introduction

The output growth and volatility nexus has been a very active area of research in macroeconomics, both from a theoretical and empirical perspective as it integrates business cycle and economic growth analysis into a unified framework. However, there are many different theoretical approaches and empirical findings that have produced a lot of disagreement in the literature. This paper looks at the relevant arguments from

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the theoretical and empirical literature and investigates the relationship using a recent panel GARCH in mean modeling augmented to include a set of additional conditioning variables.

The main theoretical arguments outlining the impact of output variability on output growth can be placed into three categories based on their underlying prediction of a positive, negative or no association at all outcome. The first category stressing a positive link is based on the precautionary motive for savings. In that case the higher the volatility, the higher the savings will be due to the precautionary motive something that may result in higher growth within the framework of neoclassical growth theory (Sandmo 1970; Mirman 1971). In addition, riskier investments that create higher volatility would require higher returns for investment to be undertaken and as such would be growth enhancing (Black 1987). However, this outcome should be taken with caution as it applies mostly to developed economies and less so to the least developed group of countries, where higher volatility may reflect a generally adverse business environment and may not lead to higher investment.

The second category calls for a negative relationship between growth and volatility due to uncertainty based on a Keynesian argument. Keynes (1936) argued that economic growth declines when there would be a rise in (economic) volatility due to the fact that entrepreneurs perceive the environment riskier and hence lower their investment. Similarly, Bernanke (1983) and Pindyck (1990) present a negative link based on the argument that firms become unable to reverse investment decisions in the presence of uncertainty.

The last category is the one that was prevalent in the early literature, where the business cycle and economic growth theory did not take that link into consideration (Kydland and Prescott 1982; Long Jr and Plosser 1983; King et al. 1988). In that approach, there is a presumed independence between output variability and growth as the determinants of these two variables are deemed to be different from each other. It is argued that volatilities in output occur due to price mis-perceptions following a monetary shock, whereas changes in output growth emerge due to real shocks such as technology shocks (Friedman 1968).

To summarize, the theoretical link can be negative or positive. The negative effect stems from a mixture of three theories. Together with a rise in growth rate, inflation rate is expected to be higher using Phillips curve type arguments, which describe a negative link between inflation and unemployment. Higher inflation will create further higher inflation uncertainty according to Friedman (1977) and as such due to the trade-off between inflation uncertainty and output uncertainty (Taylor 1979), higher inflation uncertainty will create a decline in output volatility. On the other hand, the positive impact of output growth on output volatility is also based on Taylor (1979). A lower growth rate will push monetary authority to lower interest rates which will increase inflation and hence inflation uncertainty which will further lower output volatility due to the trade-off between the last two.

In our paper, we investigate the output growth and volatility nexus in a model that allows for a bidirectional relationship between the two employing a variant of the panel GARCH in mean (GARCH-M) work of Cermeño and Grier (2006). In this context, the conditional mean equation is expressed in a dynamic panel form with the conditional variance (or standard deviation) added as an additional regressor in the mean equation,

while the lagged dependent variable of the mean equation is added as a regressor in the variance equation. This methodology enables us to simultaneously analyze the relationship between output and its volatility. An additional advantage of our approach compared to basic GARCH models using country-by-country basis is that it takes into account the heterogeneity across countries and as such it allows for potential cross-sectional dependence through the conditional covariance equation. Furthermore, we extend the existing literature by allowing for the presence of additional independent variables in the conditional mean and (co)variance equations. These variables are classified as policy, institutional and trade openness variables, which are arguably crucial determinants of output growth and its volatility. The impact of institutions on economic growth has been extensively examined in the literature. Institutional variables, in the recent literature, are argued to be the main reason behind economic differences (Acemoglu and Robinson 2010; Acemoglu et al. 2005; Acemoglu 2010). It is argued that better governmental/institutional structures, alleviating the burden on business conditions, contribute to growth (Barro 1996; Dawson 1998; Bassanini and Scarpetta 2002; Aisen and Veiga 2013; Easterly et al. 2006; Esfahani and Ramirez 2003). Barro (2013) highlights the importance of institutions and places them among the most important determinants of cross country differences in long run economic growth and living standards and more recently, Nawaz (2015) comes to the same conclusion. Similarly, the impact of trade on economic growth has been extensively examined in the literature with mixed results. Positive effects of trade liberalization on growth are based on the decline in the cost of inputs, increase in the job opportunities in service sector, rise in productivity through competition and improved stability due to the contributions to global value chain (Sachs et al. 1995; Edwards 1998; Karam and Zaki 2015; Kim et al. 2016). However, there are also several empirical studies that are unable to identify a positive link and the effect may change based on the dataset (Rodriguez and Rodrik 2000; Lee et al. 2004; Rodrik et al. 2004; Schularick and Solomou 2011). The timing of the trade liberalization may also matter since it may have a distortionary effect in problematic periods by discouraging efficient resource reallocations (Falvey et al. 2012) and additional possible negative effects occur through an increase in investment fluctuations (Karras 2006; Razin and Rose 1992).

We expect that these additional variables will enhance the ability of the model to better explain the output growth and volatility nexus in the context of our GARCH-M framework. Finally, the paper is also novel in terms of the number of countries and country groups that are included in the analysis as we use as an extensive data set as it is possible including many more country groups and countries than before.

The rest of the paper is organized as follows. Section 2 presents the recent theoretical and empirical literature between output growth and its volatility. Section 3 presents the model and data. Section 4 reports the empirical findings. Section 5 concludes the paper.

## 2 Recent literature

As mentioned above the standard earlier theoretical arguments outlining the impact of output variability on output growth can lead to all possible different predictions,

that is a positive, negative or no association at all outcome. Furthermore, there is also no theoretical consensus regarding the reverse impact of output growth on output volatility.

More recently, the link between output growth and output volatility is investigated in several theoretical economic models. Blackburn (1999) finds that business cycle volatility increases the long-run growth rate using an endogenous growth model. Grinols and Turnovsky (1998) and Turnovsky (2000) using a stochastic monetary growth model and a stochastic growth model where money is super-neutral, respectively, show that growth rate is positively related with output volatility. In the context of a small open-economy stochastic general equilibrium model, Turnovsky and Chattopadhyay (2003) find that output volatility has an ambiguous effect on growth, whereas Blackburn and Galindez (2003) argue that the sign of the correlation between output growth and volatility is based on the source of technological change. Furthermore, Blackburn and Pelloni (2004) using a stochastic monetary growth model state that the above correlation is dependent on the type of shock, whereas Blackburn and Pelloni (2005), using an extensive form of their previous model, they find that output growth and output variability are negatively correlated irrespective of the type of shock.

As for the empirical literature, there are several methodologies adapted to investigate the link between output growth and its volatility. Yet on the whole, the evidence to date on the association between output variability and output growth is inconclusive. Kormendi and Meguire (1985) and Grier and Tullock (1989) using cross-country analysis, Caporale and McKiernan (1998) and Grier et al. (2004) for US data and Caporale and McKiernan (1996) using UK data find a positive association between output variability and growth; on the other hand, Zarnowitz and Moore (1986) and Henry and Olekalns (2002) for US data, Ramey and Ramey (1995) and Kneller and Young (2001) using a panel data, Hnatkovska and Loayza (2004) for low-income countries found evidence for a negative relationship; finally some papers have mixed or no evidence for the relationship for different countries or country groups (Speight 1999; Grier and Perry 2000; Fountas et al. 2002, 2004; Imbs 2007; Alimi 2016; Salton and Ely 2017). In terms of GARCH models, those that have appeared in the literature have been used mostly within a single country approach. Furthermore, studies using the simpler version of the panel GARCH-M model have recently appeared in other applied areas (Lee and Valera 2016; Valera et al. 2017a, b) yet, panel dynamic GARCH-M models with lagged dependent in the conditional variance model as well, are only a few (Cermeño and Sanin 2015; Ribeiro et al. 2017). However, all the above papers do not include any additional regressors beyond lagged variables in the GARCH-M specification.

In the output growth and volatility context examining a possible two-way relationship, Fountas and Karanasos (2006) find a positive effect of volatility on growth but negative effect of growth on volatility, using a variant of the GARCH-M model for 3 developed countries; Lee (2010) also finds positive effect of volatility on growth for seven developed countries but no evidence for the inverse link using a panel GARCH-M; Tsouma (2014) using a GARCH model for the Greek economy and Antonakakis and Badinger (2016) using VAR model for 7 developed countries also find a negative link for both direction. In terms of scope of data, Trypsteen (2017) observed a positive association between domestic volatility and growth and a negative association between external volatility and growth using an augmented GARCH model for 13

OECD countries; Salton and Ely (2017), using monthly industrial production of seven emerging and seven developed countries with a panel GARCH-M model that captures the one-way link from volatility to growth, find a positive effect for developed countries; however, the effect turns out to be negative for emerging markets. In our paper, we will use a much more extensive data set that includes the largest number possible of developed and developing countries including emerging markets.

### 3 The model and data

#### 3.1 Data

This study employs annual data for the period of 1971–2014 for 82 countries divided into several country groups based on their development level and region. The countries included each classification is presented in Table 2 and explanations are given in Sect. 4. Output growth,  $y$  is GDP growth rate at constant prices. Volatility is the conditional standard deviation from a panel GARCH-M model augmented to include additional regressors. These fall into three main categories, openness, institutional and policy variables. Trade openness ( $TO$ ) is selected as a proxy for openness given data availability for the set of countries that we have at our disposal. It is defined as total imports and exports as a ratio of GDP. As policy variable, we selected government expenditures ( $GOV$ ) for the same reason expressed as ratio of GDP.  $TO$ ,  $GOV$  and  $y$  are obtained from World Development Indicators. As for institutional variables, there are the political rights and civil liberties indices available from the Freedom House website taking into account the time span that we analyze. Both indices are highly correlated and are close substitutes for each other. The civil liberties index ( $CL$ ) is selected as a proxy for institutions as it displays more variation over the time compared with the political rights index. The indices take values from 1 to 7 where 1 refers to the highest achievement of freedom (freest) and 7 to the lowest level (least free). Table 1 shows the descriptive statistics. All variables are checked for stationarity;  $GOV$  and  $TO$  are found to have unit roots and we use their first differences instead.<sup>1</sup>

Figure 1 shows the volatility of GDP growth rates for different country groups calculated as 15-year non-overlapping standard deviations. The figure<sup>2</sup> reveals that developed countries exhibit the least volatility and that emerging markets are less volatile compared with the developing countries. The figure shows a pattern of declining volatility together with a rise in development. High growth volatility is generally linked to under-development or acts as an impediments to development, in a similar way as low institutional quality (Acemoglu et al. 2003). Moreover, volatilities decline over time, in line with Kose et al. (2003), except for the last period of European developed countries. This can be attributed to the deep and prolonged European crisis that is even likely to continue due to uncertainty surrounding Brexit, problems in the European banking system and the level of government debt in Greece.

<sup>1</sup> Panel unit root test results are available on demand.

<sup>2</sup> All countries in World Bank database having GDP growth rates available are included.

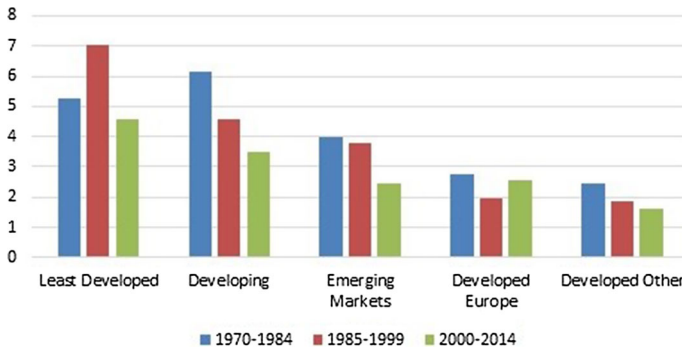
**Table 1** Descriptive statistics

	y	CL	GOV	TO	y	CL	GOV	TO
	<i>Developed EU</i>				<i>Developed non-EU</i>			
Mean	0.03	1.30	0.20	0.81	0.03	1.12	0.18	0.34
Maximum	0.13	6.00	0.28	3.74	0.08	2.00	0.25	0.83
Minimum	-0.08	1.00	0.10	0.26	-0.06	1.00	0.11	0.11
SD	0.03	0.73	0.04	0.51	0.02	0.33	0.03	0.17
Skewness	-0.14	4.15	-0.23	2.84	-0.68	2.31	0.21	1.00
Kurtosis	4.73	24.99	2.71	13.19	4.36	6.32	2.43	3.25
Observations	630	630	630	630	180	180	180	180
	<i>Emerging markets</i>				<i>Sub-Saharan</i>			
Mean	0.05	3.81	0.12	0.42	0.05	4.50	0.17	0.87
Maximum	0.19	7.00	0.28	1.10	0.40	7.00	0.40	2.10
Minimum	-0.13	1.00	0.03	0.05	-0.24	2.00	0.06	0.06
SD	0.04	1.42	0.04	0.20	0.06	1.34	0.07	0.38
Skewness	-0.73	0.24	1.01	0.55	0.77	-0.36	1.38	0.60
Kurtosis	5.08	2.25	4.54	3.36	8.69	2.13	4.55	2.94
Observations	630	630	630	630	360	360	360	360
	<i>South Asia</i>				<i>MENA</i>			
Mean	0.05	4.29	0.09	0.42	0.04	5.04	0.20	0.71
Maximum	0.11	5.00	0.18	0.89	0.27	7.00	0.43	1.29
Minimum	-0.14	2.00	0.03	0.11	-0.22	2.00	0.08	0.14
SD	0.03	0.73	0.03	0.20	0.06	1.36	0.07	0.22
Skewness	-2.48	-0.62	0.13	0.69	0.16	-0.83	1.01	0.12
Kurtosis	16.34	2.51	2.29	2.27	6.73	3.01	3.68	2.66
Observations	135	135	135	135	314	314	315	314
	<i>Latin America</i>				<i>East Asia</i>			
Mean	0.03	2.93	0.13	0.72	0.06	3.91	0.13	1.70
Maximum	0.18	7.00	0.43	2.80	0.15	6.00	0.20	4.40
Minimum	-0.27	1.00	0.03	0.20	-0.08	2.00	0.08	0.34
SD	0.04	1.13	0.05	0.36	0.04	0.94	0.03	1.09
Skewness	-0.89	0.43	1.66	2.09	-0.66	-0.45	0.39	0.94
Kurtosis	7.74	3.20	8.24	9.28	3.33	2.43	2.14	2.54
Observations	585	585	585	585	180	180	180	180
	<i>Least developed</i>							
Mean	0.03	5.04	0.14	0.57				
Maximum	0.35	7.00	0.64	3.22				
Minimum	-0.50	2.00	0.02	0.13				
SD	0.06	1.34	0.07	0.34				
Skewness	-1.12	-0.43	2.58	3.28				

**Table 1** continued

	y	CL	GOV	TO	y	CL	GOV	TO
Kurtosis	15.97	2.38	14.57	20.12				
Observations	675	675	629	665				

*y*, *CL*, *GOV*, *TO* refer to GDP growth, civil liberties index, government expenditure and trade openness, successively. The last two variables are used as a ratio of GDP. The data cover the period 1971–2014



**Fig. 1** Volatility of GDP growth rate (%). *Notes:* Standard deviation measurement is used for volatility

### 3.2 Panel GARCH-M model

We consider a dynamic panel conditional mean equation with a set of independent variables in the form of institutions, policy and openness and conditional standard deviation as a measure for volatility. The model includes fixed effects to control for country-specific factors. Moreover, exogeneous variables are employed in their lagged values, i.e.,  $CL_{i,t-1}$ ,  $GOV_{i,t-1}$ ,  $TO_{i,t-1}$ , in order to alleviate the potential endogeneity problem.

$$y_{i,t} = \beta_i + \alpha y_{i,t-1} + \kappa \sigma_{i,t} + \eta CL_{i,t-1} + \theta GOV_{i,t-1} + \tau TO_{i,t-1} + \epsilon_{i,t} \quad (1)$$

$i = 1, \dots, N$ ;  $t = 1, \dots, T$ , where  $N$  is the number of cross sections and  $T$  is the time periods;  $\beta_i$  is the country-specific effect and  $\alpha$  is the autoregressive coefficient;<sup>3</sup>  $\kappa$  is the coefficient of the conditional standard deviation as a measure for volatility;  $\eta$ ,  $\theta$  and  $\tau$  are the coefficients of the independent variables.  $\epsilon_{i,t}$  is the disturbance error with zero mean and normal distribution with the conditional moments given in Eqs. (2)–(5):

<sup>3</sup> We assume common effects considering that the panel data consists of similar countries with respect to their development levels and geographical location. We also assume AR(1) process for the mean equations considering that the time frequency is annual and taking into account of the small time span.

$$E[\epsilon_{i,t}\epsilon_{j,s}] = 0 \text{ for } i \neq j \text{ and } t \neq s \quad (2)$$

$$E[\epsilon_{i,t}\epsilon_{j,s}] = 0 \text{ for } i = j \text{ and } t \neq s \quad (3)$$

$$E[\epsilon_{i,t}\epsilon_{j,s}] = \sigma_{ij,t} \text{ for } i \neq j \text{ and } t = s \quad (4)$$

$$E[\epsilon_{i,t}\epsilon_{j,s}] = \sigma_{i,t}^2 \text{ for } i = j \text{ and } t = s \quad (5)$$

Equation (2) assumes no non-contemporaneous cross-sectional correlation; Eq. (3) assumes no autocorrelation; Eqs. (4) and (5) are the assumptions for a general conditional variance-covariance process. Following the model of Cermeño and Grier (2006), the conditional variance and covariance processes of output are defined in Eqs. (6) and (7), successively. We assume GARCH(1,1) process for conditional variance and covariance equation taking into account the literature.

$$\begin{aligned} \sigma_{i,t}^2 = & \phi_i + \delta\sigma_{i,t-1}^2 + \gamma\epsilon_{i,t-1}^2 + \mu y_{i,t-1} \\ & + v_c CL_{i,t-1} + v_t TO_{i,t-1} + v_g GOV_{i,t-1}, i = 1, \dots, N. \end{aligned} \quad (6)$$

$$\begin{aligned} \sigma_{ij,t} = & \varphi_{ij} + \lambda\sigma_{ij,t-1} + \rho\epsilon_{i,t-1}\epsilon_{j,t-1} + \zeta_c CL_{i,t-1} \\ & + \zeta_t TO_{i,t-1} + \zeta_g GOV_{i,t-1}, i \neq j. \end{aligned} \quad (7)$$

In matrix notation, Eq. (1) can be written in this form:

$$y_t = \beta + Z_t\theta + \epsilon_t, \quad (8)$$

$t = 1, \dots, T$ , where  $y_t$ ,  $\epsilon_t$  are vectors of dimension  $N \times 1$ .  $\beta$  is  $N \times 1$  vector of country specific effects.  $Z_t$  is a matrix of all right-hand-side variables of dimension  $N \times x(K + 1)$ , where  $K$  is the number of slope coefficients except for autoregressive one.  $\theta$  is a column vector of coefficients. The vector of error term,  $\epsilon_t$ , has a multivariate normal distribution with zero mean and time-dependent covariance matrix  $N(0, \Omega_t)$ . The covariance matrix has diagonal and off-diagonal elements as given in Eqs. (6) and (7), respectively. Since error term is conditional heteroscedastic and cross-sectionally correlated, least squares estimator will no longer be efficient. Hence, maximum likelihood method is used to handle this problem. The log-likelihood function for the complete panel is as follows:

$$L = -\frac{1}{2}NT \ln(2\pi) - \frac{1}{2} \sum_{t=1}^T \ln |\Omega_t| - \frac{1}{2} \sum_{t=1}^T [(y_t - \beta - Z_t\theta)' \Omega_t^{-1} (y_t - \beta - Z_t\theta)] \quad (9)$$

The panel GARCH model maximizes above equation.<sup>4</sup> We estimate five different panel GARCH models. Model A is simply a panel extended version of the GARCH model with the conditional covariance equation. In model B, the conditional standard deviation is added as an additional regressor in the mean equation, whereas in model C, lagged output growth is included as an additional regressor in the conditional variance equation. Models D and E are our augmented models incorporating independent

<sup>4</sup> RATS codes GARCHMV.PRG are used and revised according to our methodology.



**Table 2** Country groups

Developed EU	Austria, Belgium, Denmark, Finland, France, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom
Developed non-EU	Australia, Canada, Japan, United States
Emerging markets	Argentina, Brazil, Chile, China, Colombia, Egypt, India, Indonesia, South Korea, Mexico, Peru, Philippines, South Africa, Turkey
Developing Countries: Sub-Saharan	Botswana, Cote d'Ivoire, Cameroon, Congo Rep., Gabon, Ghana, Kenya and Lesotho
Developing Countries: South Asia	Bangladesh, Pakistan and Sri Lanka
Developing Countries: MENA	Algeria, Iran, Israel, Morocco, Oman, Saudi Arabia and Tunisia
Developing Countries: Latin America and Caribbean	Bolivia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Nicaragua, Trinidad and Tobago, Uruguay and Venezuela
Developing Countries: East Asia	Fiji, Malaysia, Singapore and Thailand
Least Developed Countries	Benin, Burkina Faso, Burundi, Central African Republic, Chad, Madagascar, Malawi, Mali, Mauritania, Niger, Rwanda, Senegal, Sierra Leone, Sudan and Togo

variables to the conditional equations. Model D includes independent variables in the conditional mean equation, whereas model E includes independent variables in the conditional variance and covariance equations as an extension of D. When interpreting results we focus mainly on those of model E as it constitutes most encompassing model, while we rely on the other results for robustness purposes and present them in "Appendix".

## 4 Empirical results

Table 3 presents the estimation results for different country classifications from the developed world to emerging markets and from least developed countries to developing nations with its geographic variants.<sup>5</sup> The countries included in each classification are presented in Table 2. The developed countries are divided into EU and non-EU blocks, while the Emerging market countries are selected as the pool of JP Morgan EMBI+, which is referred by UNCTAD,<sup>6</sup> MSCI Emerging Markets Index<sup>7</sup> and Columbia University's Emerging Market Global Players. We used UNCTAD regional country classifications when forming the remaining country groups. In all cases country selections are also affected by the data availability for the relevant variables.

<sup>5</sup> Estimates are small and they may be economically insignificant.

<sup>6</sup> [http://unctadstat.unctad.org/EN/Classifications/UnctadStat.EconomicGroupings.Criteria\\_EN.pdf](http://unctadstat.unctad.org/EN/Classifications/UnctadStat.EconomicGroupings.Criteria_EN.pdf).

<sup>7</sup> <https://www.msci.com/acwi>.

As shown in Table 3, the impact of volatility on growth,  $\kappa$ , turns out to be significant and positive for seven country groups out of nine. Except for the two country groups, namely as emerging markets (EM) and least developed countries (LD), we may argue that higher volatility is associated with higher growth. The positive link seems to be in line with the precautionary motive or the risk-return trade-off in the literature. Emerging and least developed countries seem to lack this link given the time horizon and the methodology used. In fact, emerging country group reflects significance at 10% which will be theoretically consistent if statistically approved, given the growth potential of this country group.

The impact of growth on volatility, which is captured by  $\mu$ , also varies across country groups. This effect is found to be significant in seven out of nine country groups with the exclusion of least developed and EU country groups. Among those seven groups, five reflect positive effect, except for the non-European developed countries and MENA group. Positive result suggests that higher growth brings about higher volatility, implying that the higher the growth, the less predictable it is.<sup>8</sup>

The institutional variable, whose effect is captured by  $\eta$ , is observed to be significant for seven out of nine country groups with the exceptions of EM and SS. For four out of seven (Non-EU, SA, LA&C, LD) country groups, we observe a negative impact on growth. Note that a rise in the institutional variable refers to a decline in institutional quality. Hence, for the majority of the country groups the increase in institutional quality increases growth. For the remaining country groups (EU, MENA and EA), the institutional variable reflects a positive impact, i.e., institutional quality hampers growth, which may be attributed to bureaucratic procedures. Regarding the effect on volatility, denoted by  $\nu_c$ , all groups except for SA reflect a positive impact, suggesting that the better the institutional quality, the lower the growth volatility rate will be. Trade openness ( $\tau$ ) is observed to be contributing to growth rate in all groups except for NEU and LA&C and helps to reduce volatility ( $\nu_t$ ) in SA, MENA and EA. For NEU, EM and SS country groups, trade openness rises output volatility. Government expenditure ( $\theta$ ) affects growth positively only for MENA countries. Negative results obtained for SA, LA&C and EA are consistent with neoclassical theory that a rise in government expenditures is likely to increase interest rates which will further lower output growth in a dynamic setting. The effect of government expenditures on volatility ( $\nu_g$ ) appear to be significant in seven country groups with the exclusion of EM and LA&C. For two of them (SS, LD), an increase in government expenditures pushes the volatility upward, whereas for five of them, the effect is in the opposite direction.

Another finding worth mentioning is the autoregressive coefficient of the mean equation,  $\alpha$ , which turns out to be the significant for all except for the least developed countries which disregards the persistence of growth for these countries as expected due to their unstable and unpredictable structure.

In "Appendix," we provide complete estimation results for all models covered from A to E through Tables 4, 5, 6, 7, 8, 9, 10, 11 and 12. Overall, models D and E, the GARCH-M models incorporating independent variables, are observed to display a better fit in terms of the values of their respective log-likelihood functions as available in the last row of table and offer an improvement over the other simpler models.

<sup>8</sup> See for example the results of Cermeño and Grier (2006).

**Table 3** Panel GARCH model

	(EU)	(NEU)	(EM)	(SS)	(SA)	(MENA)	(LA&C)	(EA)	(LD)
<i>Mean equation</i>									
$\alpha$	3.9E-01* (4.2E-02)	1.7E-01* (5.7E-02)	4.5E-01* (3.2E-02)	4.4E-01* (3.4E-02)	2.5E-01* (3.5E-03)	1.2E-01* (2.2E-04)	5.1E-01* (3.5E-02)	1.4E-01* (2.0E-05)	3.1E-02 (6.3E-02)
$\kappa$	2.2E-01* (8.8E-02)	1.2E+00* (1.4E-01)	9.5E-02 (5.7E-02)	3.3E-01* (8.2E-02)	3.3E-02* (7.0E-05)	4.9E-02* (+)(2.0E-04)	3.7E-01* (6.5E-02)	3.0E-03* (2.8E-05)	1.0E-02 (6.5E-02)
$\eta$	2.9E-03* (6.2E-04)	-2.7E-02* (3.3E-03)	-7.3E-04 (4.8E-04)	-1.1E-04 (8.8E-04)	-8.1E-04* (2.9E-05)	4.5E-04* (8.1E-06)	-9.1E-04* (4.7E-04)	3.9E-04* (1.0E-06)	-5.5E-03* (7.8E-04)
$\theta$	1.3E-02 (1.9E-02)	1.0E-02 (1.5E-02)	3.6E-03 (1.0E-02)	-2.8E-03 (2.0E-02)	-1.5E-02* (1.5E-03)	4.0E-02* (3.6E-04)	-2.2E-02* (7.2E-03)	-2.7E-02* (2.7E-05)	8.7E-03 (1.2E-02)
$\tau$	4.4E-02* (1.2E-02)	-4.4E-02 (4.1E-02)	3.3E-02* (8.8E-03)	5.5E-02* (8.9E-03)	2.9E-02* (3.7E-04)	5.2E-02* (8.0E-04)	6.9E-03 (7.0E-03)	3.3E-02* (3.7E-05)	4.6E-02* (8.6E-03)
<i>Variance equation</i>									
$\delta$ (GARCH)	8.1E-01* (2.3E-04)	7.8E-01* (1.0E-03)	8.0E-01* (2.3E-03)	7.9E-01* (1.3E-04)	6.6E-01* (1.4E-05)	8.1E-01* (7.4E-07)	8.0E-01* (3.2E-05)	7.9E-01* (8.2E-07)	8.2E-01* (9.1E-04)
$\gamma$ (ARCH)	1.0E-01* (2.4E-03)	1.2E-01* (2.1E-03)	1.2E-01* (3.2E-03)	1.0E-01* (1.7E-03)	9.1E-02* (5.7E-04)	1.1E-01* (3.3E-05)	1.1E-01* (1.8E-03)	9.9E-02* (7.9E-07)	1.0E-01* (2.6E-03)
$\mu$	2.8E-05 (3.5E-05)	-5.9E-04* (1.4E-05)	5.5E-04* (1.0E-04)	2.5E-03* (9.8E-05)	4.4E-03* (2.7E-07)	-1.8E-03* (1.6E-06)	3.6E-04* (4.9E-05)	3.2E-04* (4.4E-07)	3.5E-05 (3.7E-04)
$\nu_C$	1.4E-06* (1.1E-07)	3.3E-04* (3.0E-06)	1.9E-05* (1.1E-06)	8.9E-05* (1.5E-07)	-3.4E-05* (5.1E-08)	5.1E-05* (2.0E-07)	1.1E-05* (1.1E-06)	7.4E-05* (2.2E-07)	6.9E-05* (2.4E-06)
$\nu_I$	-7.3E-06 (8.8E-06)	5.1E-04* (3.0E-05)	2.6E-04* (7.0E-05)	9.2E-04* (3.5E-04)	-6.8E-04* (7.8E-06)	-1.8E-03* (3.7E-05)	1.7E-04 (9.5E-05)	-6.7E-04* (3.8E-07)	-2.7E-04 (3.0E-04)
$\nu_g$	-5.9E-05* (4.4E-06)	-4.3E-04* (9.7E-05)	2.8E-04 (1.6E-04)	1.2E-04* (1.7E-05)	-1.6E-04* (3.5E-06)	-9.9E-03* (2.4E-06)	1.4E-05 (4.1E-05)	-3.6E-04* (4.6E-07)	1.3E-03* (3.2E-04)

Table 3 continued

	(EU)	(NEU)	(EM)	(SS)	(SA)	(MENA)	(LA&C)	(EA)	(LD)
<i>Covariance equation</i>									
$\lambda$	7.9E-01*	8.0E-01*	7.8E-01*	8.0E-01*	7.8E-01*	7.4E-01*	7.8E-01*	8.1E-01*	8.0E-01*
	(6.8E-04)	(9.7E-04)	(7.6E-04)	(1.1E-04)	(6.6E-04)	(7.4E-06)	(2.4E-05)	(3.0E-03)	(8.3E-04)
$\rho$	9.1E-02*	6.7E-02*	9.1E-02*	9.0E-02*	3.4E-02*	8.3E-02*	8.4E-02*	9.6E-02*	9.2E-02*
	(2.8E-03)	(2.4E-03)	(3.8E-03)	(2.1E-03)	(6.9E-04)	(8.3E-05)	(1.1E-03)	(2.7E-03)	(3.0E-03)
$\zeta_c$	4.8E-06*	3.0E-04*	3.3E-05*	1.1E-04*	9.5E-07*	-6.8E-06*	1.6E-05*	5.0E-05*	7.4E-05*
	(2.7E-07)	(3.0E-06)	(1.0E-06)	(1.4E-09)	(1.7E-07)	(1.7E-07)	(1.0E-06)	(2.6E-06)	(3.9E-08)
$\zeta_t$	2.7E-05	-1.0E-03*	-1.5E-04*	-1.3E-03*	-4.3E-04*	1.7E-03*	-1.5E-04	4.9E-04*	4.8E-04
	(4.9E-05)	(9.0E-05)	(7.5E-05)	(3.7E-04)	(2.5E-05)	(3.0E-05)	(9.5E-05)	(2.0E-04)	(2.9E-04)
$\zeta_g$	-3.5E-05	5.6E-04*	2.6E-04	4.1E-04*	5.5E-04*	-4.1E-04*	-1.2E-04*	-2.1E-05	3.1E-04
	(6.3E-05)	(9.9E-05)	(1.7E-04)	(2.1E-05)	(1.4E-06)	(1.3E-06)	(5.7E-05)	(6.1E-05)	(3.2E-04)
Log-likelihood	1.7E+03	474.765	1267.393	576.452	302.601	513.830	1189.557	349.347	1062.011

Standard errors are given in paranthesis

(\*) indicate significance at 5%. (EU) Developed EU countries; (NEU) denotes Developed Non-EU countries; (EM) denotes Emerging markets countries; (SS) denotes Sub-Saharan countries; (SA) denotes South Asian countries; (MENA) denotes MENA countries; (LA&C) denotes Latin America and Caribbean countries; (EA) denotes East Asian countries; and (LD) denotes Least Developed countries. All the parameters were estimated simultaneously by maximum likelihood. Country effects ( $\beta_i$ ) are removed in this summary table.  $\phi_i$  and  $\varphi_{ij}$  are not presented to save space but can be provided on demand. Data period is 1971–2014 ( $T = 44$ )

## 5 Conclusion

This paper focuses on the relationship between output growth and its volatility using 82 countries divided into country groups for the period 1971–2014. The methodology used is based on a panel GARCH-M model which in its simplest form has also been used in the recent literature. Our paper uses an extension of this model that allows for the presence of independent variables in the conditional equations applied to a much larger set of countries than had been done so far. Overall, we conclude that the two-way relationship between output growth and output volatility is observed to be different for each country group. The evidence regarding the impact of volatility on growth seems to be strong as seven country groups out of nine confirm positive sign. However, the effect of growth on volatility is mixed as the sign and significance is changing depending on the country group. Least developed country group is the only group to disregard any significant link between growth and volatility.

We have mixed evidence across country groups for exogenous variables, i.e., openness, institutional and policy variables except for two strong empirical evidence: (i) trade openness seems to contribute to growth as seven out of nine country groups confirm the positive sign; (ii) institutional quality is observed to lower output volatility except for a single country group. The finding (i) is consistent with the literature praising the benefits of trade liberalizations (Grossman and Helpman 1990; Romer 1990; Young 1991). The finding (ii) is consistent with the prominent work of Acemoglu et al. (2003) stating that distortionary macroeconomic policies, put it differently, poor institutions are more likely to create macroeconomic volatility.

Overall, we found that the additional variables have produced additional evidence that shows a heterogeneous pattern among the different country groups we considered. In that respect, the output growth and volatility nexus seems to differ according to the level of development that characterized the different groups of countries that we considered and as such we can say that there is no unique pattern that fits all.

## Appendix

Model (A) denotes Panel Garch model (with conditional covariance); (B) denotes Panel Garch-M model: conditional mean is incorporated to Model (A); (C) denotes Panel Garch-M model with lagged dependent variable in the conditional variance equation; (D) incorporates independent variables to model (C) inside the conditional mean equation; finally (E) incorporates independent variables inside the conditional variance and covariance equations, as a further step to model (D) as given in Eqs. 1, 6 and 7 (Tables 4, 5, 6, 7, 8, 9, 10, 11, 12).

**Table 4** Panel GARCH model for developed EU countries

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	4.1E-03* (1.2E-03)	5.5E-03* (1.5E-03)	3.1E-03* (1.2E-03)	2.4E-03* (6.2E-06)	3.4E-03* (1.6E-03)
$\beta_2$	3.8E-03* (1.2E-03)	4.9E-03* (1.1E-03)	2.9E-03* (1.2E-03)	9.5E-04* (4.2E-06)	2.9E-03 (1.7E-03)
$\beta_3$	-7.8E-04 (1.1E-03)	4.0E-03* (1.3E-03)	-2.0E-03* (8.7E-04)	-2.0E-03* (4.3E-06)	3.4E-04 (1.9E-03)
$\beta_4$	4.5E-03* (1.1E-03)	5.5E-03* (1.4E-03)	6.7E-04 (4.5E-04)	2.0E-03* (1.2E-05)	1.5E-03 (2.5E-03)
$\beta_5$	2.8E-03* (4.7E-04)	4.0E-03* (7.4E-04)	2.0E-03* (7.7E-05)	-1.2E-03* (2.0E-04)	9.6E-04 (1.0E-03)
$\beta_6$	1.0E-02* (3.6E-03)	1.2E-02* (2.8E-03)	1.0E-02* (2.7E-03)	1.0E-02* (7.3E-06)	6.5E-03 (3.8E-03)
$\beta_7$	-1.8E-03* (7.9E-04)	8.3E-04 (1.1E-03)	-4.6E-03* (7.5E-04)	-6.1E-03* (6.0E-06)	-2.8E-03 (1.6E-03)
$\beta_8$	9.3E-03* (1.9E-03)	9.1E-03* (2.2E-03)	5.1E-03* (1.4E-03)	5.9E-03* (2.4E-05)	4.7E-03 (3.7E-03)
$\beta_9$	4.6E-03* (1.0E-03)	5.7E-03* (7.2E-04)	3.9E-03* (9.5E-04)	2.0E-03* (9.5E-04)	2.8E-03* (1.4E-03)
$\beta_{10}$	1.2E-02* (1.1E-03)	1.5E-02* (1.3E-03)	1.5E-02* (8.0E-04)	1.2E-02* (4.4E-04)	1.4E-02* (1.3E-03)
$\beta_{11}$	1.7E-03 (1.2E-03)	3.1E-03 (2.4E-03)	-3.9E-04 (2.1E-03)	-2.7E-03* (1.8E-05)	-1.5E-03 (2.6E-03)
$\beta_{12}$	6.8E-03* (9.7E-04)	7.1E-03* (1.3E-03)	5.5E-03* (2.3E-04)	2.0E-04 (8.5E-04)	5.9E-04 (1.7E-03)
$\beta_{13}$	3.9E-03* (1.5E-03)	5.2E-03* (1.2E-03)	2.6E-03 (1.6E-03)	1.5E-03* (1.0E-05)	2.1E-03 (1.6E-03)
$\beta_{14}$	7.2E-03* (1.4E-03)	8.2E-03* (8.3E-04)	5.0E-03* (1.5E-03)	2.8E-03* (9.0E-04)	2.4E-03 (2.2E-03)
$\alpha_1$	4.6E-01* (1.2E-02)	4.4E-01* (2.5E-02)	3.4E-01* (1.9E-03)	3.8E-01 (9.2E-03)	3.9E-01 (4.2E-02)
$\kappa$		8.3E-02* (4.0E-02)	1.0E-04 (2.6E-03)	2.7E-02* (8.4E-07)	2.2E-01* (8.8E-02)
$\eta$				3.2E-03* (1.7E-04)	2.9E-03* (6.2E-04)
$\theta$				3.0E-02* (4.5E-05)	1.3E-02 (1.9E-02)
$\tau$				4.7E-02* (5.8E-07)	4.4E-02* (1.2E-02)

**Table 4** continued

	(A)	(B)	(C)	(D)	(E)
<i>Variance equation</i>					
$\delta$ (GARCH)	7.9E-01* (3.9E-04)	8.0E-01* (2.7E-04)	8.0E-01* (3.2E-05)	8.0E-01* (6.1E-07)	8.1E-01* (2.3E-04)
$\gamma$ (ARCH)	1.0E-01* (5.9E-04)	9.8E-02* (5.6E-04)	1.1E-01* (8.1E-05)	1.0E-01* (7.0E-07)	1.0E-01* (2.4E-03)
$\mu$			-9.2E-05* (1.4E-06)	-7.3E-06* (2.6E-07)	2.8E-05 (3.5E-05)
$\nu_c$					1.4E-06 (1.1E-07)
$\nu_t$					-7.3E-06 (8.8E-06)
$\nu_g$					-5.9E-05 (4.4E-06)
<i>Covariance equation</i>					
$\lambda$	7.9E-01* (4.2E-04)	7.9E-01* (2.7E-04)	7.9E-01* (6.2E-05)	7.9E-01* (4.1E-04)	7.9E-01* (6.8E-04)
$\rho$	7.7E-02* (7.1E-04)	7.8E-02* (1.3E-03)	8.9E-02* (8.5E-05)	8.5E-02* (6.2E-04)	9.1E-02* (2.8E-03)
$\zeta_c$					4.8E-06 (2.7E-07)
$\zeta_t$					2.7E-05 (4.9E-05)
$\zeta_g$					-3.5E-05 (6.3E-05)
Log-likelihood	1725.4259	1725.4259	1725.4259	1736.8136	1736.8136

Countries included are Austria, Belgium, Denmark, Finland, France, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom.  $N = 14$

**Table 5** Panel GARCH model for developed Non-EU countries

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	2.3E-02* (7.0E-04)	2.7E-02* (5.2E-04)	9.0E-03* (2.0E-03)	3.9E-02* (2.0E-03)	2.0E-02* (1.1E-04)
$\beta_2$	1.8E-02* (8.2E-04)	2.4E-02* (1.2E-03)	1.8E-03 (1.4E-03)	3.3E-02* (1.4E-03)	-5.8E-04 (1.3E-03)
$\beta_3$	1.5E-02* (1.8E-04)	2.2E-02* (3.0E-03)	-4.1E-03 (3.1E-03)	4.8E-02* (2.2E-03)	2.1E-02* (3.1E-03)
$\beta_4$	1.8E-02* (1.8E-04)	2.3E-02* (3.0E-03)	-5.3E-05 (3.1E-03)	3.4E-02* (2.2E-03)	5.4E-03* (3.1E-03)

Table 5 continued

	(A)	(B)	(C)	(D)	(E)
$\alpha$	(1.0E-04) 3.1E-01*	(6.8E-04) 2.9E-01*	(1.6E-03) 3.1E-01*	(1.5E-03) 2.0E-01*	(5.2E-05) 1.7E-01*
$\kappa$	(2.9E-03)	(7.3E-03) -2.9E-01* (7.7E-02)	(4.1E-02) 9.3E-01* (1.0E-01)	(5.0E-02) 8.2E-01* (1.1E-01)	(5.7E-02) 1.2E+00* (1.4E-01)
$\eta$				-2.8E-02* (1.3E-03)	-2.7E-02* (3.3E-03)
$\tau$				-4.9E-02* (1.5E-02)	1.0E-02 (1.5E-02)
$\theta$				2.0E-03 (4.3E-02)	-4.4E-02 (4.1E-02)
<i>Variance equation</i>					
$\delta$ (GARCH)	9.2E-01* (1.3E-04)	9.6E-01* (1.1E-04)	9.1E-01* (5.4E-07)	8.4E-01* (9.7E-05)	7.8E-01* (1.0E-03)
$\gamma$ (ARCH)	-4.5E-02* (6.6E-04)	-4.6E-02* (1.5E-03)	1.2E-02* (8.8E-04)	4.9E-03 (9.0E-03)	1.2E-01* (2.1E-03)
$\mu$			-4.6E-04* (1.7E-06)	-5.5E-04* (1.6E-05)	-5.9E-04* (1.4E-05)
$\nu_c$					3.3E-04* (3.0E-06)
$\nu_t$					5.1E-04* (3.0E-05)
$\nu_g$					-4.3E-04* (9.7E-05)
<i>Covariance equation</i>					
$\lambda$	9.0E-01* (7.0E-03)	9.7E-01* (6.8E-04)	8.5E-01* (4.7E-07)	8.6E-01* (5.6E-05)	8.0E-01* (9.7E-04)
$\rho$	-7.6E-02* (5.0E-04)	-6.2E-02* (2.0E-03)	-2.7E-02* (4.7E-04)	-4.3E-02* (8.5E-03)	6.7E-02* (2.4E-03)
$\zeta_c$					3.0E-04* (3.0E-06)
$\zeta_t$					-1.0E-03* (9.0E-05)
$\zeta_g$					5.6E-04* (9.9E-05)
Log-likelihood	464.520	464.520	464.520	474.765	474.765

Countries included are as follows: Australia, Canada, Japan, United States.  $N = 4$



**Table 6** Panel GARCH model for emerging market countries

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	1.9E-02* (5.8E-03)	1.3E-02* (1.9E-03)	7.4E-03 (3.9E-03)	-5.8E-03 (3.9E-03)	-1.3E-03 (8.0E-03)
$\beta_2$	1.6E-02* (2.2E-03)	1.4E-02* (1.9E-04)	1.5E-02* (2.3E-03)	4.0E-03* (1.7E-03)	1.9E-03 (4.9E-03)
$\beta_3$	2.2E-02* (3.2E-03)	2.0E-02* (2.0E-05)	2.2E-02* (3.5E-03)	6.2E-03 (3.9E-03)	2.9E-03 (7.6E-03)
$\beta_4$	4.5E-02* (2.4E-03)	5.3E-02* (3.4E-04)	5.3E-02* (3.1E-03)	4.6E-02* (2.8E-03)	3.2E-02* (5.2E-03)
$\beta_5$	2.2E-02* (2.9E-03)	9.0E-03* (9.9E-05)	2.0E-02* (1.8E-03)	1.8E-02* (2.0E-03)	-5.3E-04 (2.3E-03)
$\beta_6$	2.2E-02* (2.1E-03)	3.0E-02* (1.6E-03)	2.5E-02* (2.9E-03)	2.2E-02* (1.5E-03)	1.1E-02* (4.4E-03)
$\beta_7$	1.9E-02* (1.6E-03)	3.3E-02* (6.4E-05)	3.2E-02* (3.5E-03)	2.0E-02* (1.6E-03)	6.6E-03 (4.1E-03)
$\beta_8$	2.8E-02* (3.6E-03)	2.8E-02* (1.6E-03)	2.7E-02* (3.9E-03)	1.4E-02* (2.1E-03)	1.1E-03 (2.6E-03)
$\beta_9$	3.0E-02* (3.9E-03)	3.4E-02* (2.5E-03)	3.1E-02* (3.4E-03)	1.7E-02* (3.1E-03)	8.0E-03 (6.2E-03)
$\beta_{10}$	1.2E-02* (2.7E-03)	1.5E-02* (1.7E-04)	1.3E-02* (2.0E-03)	2.8E-03 (2.0E-03)	9.6E-04 (4.2E-03)
$\beta_{11}$	1.7E-02* (4.6E-03)	7.8E-03* (2.8E-05)	1.6E-02* (8.4E-04)	-3.0E-03 (4.6E-03)	5.3E-03 (6.7E-03)
$\beta_{12}$	1.9E-02* (3.9E-03)	2.2E-02* (5.4E-04)	1.6E-02* (2.2E-03)	1.1E-02* (1.7E-03)	1.4E-03 (3.5E-03)
$\beta_{13}$	1.1E-02* (2.3E-04)	1.1E-02* (6.2E-04)	1.3E-02* (8.8E-05)	6.4E-03* (1.3E-04)	-2.3E-03 (2.7E-03)
$\beta_{14}$	1.2E-02* (4.3E-03)	1.9E-02* (3.6E-03)	1.8E-02* (4.3E-03)	4.5E-03 (3.8E-03)	-1.7E-03 (5.4E-03)
$\alpha$	4.8E-01* (3.8E-03)	4.1E-01* (7.0E-04)	4.3E-01* (1.8E-03)	4.1E-01* (2.7E-03)	4.5E-01* (3.2E-02)
$\kappa$		9.3E-04* (2.6E-04)	1.2E-02* (4.0E-03)	5.5E-01* (6.5E-03)	9.5E-02 (5.7E-02)
$\eta$				-1.1E-03 (5.4E-05)	-7.3E-04 (4.8E-04)
$\theta$				5.7E-03 (4.1E-03)	3.6E-03 (1.0E-02)
$\tau$				2.8E-02 (2.1E-03)	3.3E-02* (8.8E-03)

**Table 6** continued

	(A)	(B)	(C)	(D)	(E)
<i>Variance equation</i>					
$\delta$ (GARCH)	7.6E-01* (2.2E-04)	7.9E-01* (6.6E-06)	7.9E-01* (1.2E-05)	7.6E-01* (3.3E-04)	8.0E-01* (2.3E-03)
$\gamma$ (ARCH)	1.1E-01* (1.7E-03)	9.6E-02* (1.2E-05)	7.8E-02* (4.3E-04)	1.0E-01* (9.8E-04)	1.2E-01* (3.2E-03)
$\mu$			1.2E-04* (3.2E-06)	7.6E-06 (5.7E-06)	5.5E-04* (1.0E-04)
$\nu_c$					1.9E-05* (1.1E-06)
$\nu_t$					2.6E-04* (7.0E-05)
$\nu_g$					2.8E-04* (1.6E-04)
<i>Covariance equation</i>					
$\lambda$	8.8E-01* (2.1E-04)	8.9E-01* (2.2E-03)	8.6E-01* (9.4E-06)	8.8E-01* (5.4E-05)	7.8E-01* (7.6E-04)
$\rho$	-3.1E-02* (9.2E-04)	-3.5E-02* (2.3E-03)	-2.1E-02* (3.0E-04)	-3.1E-02* (4.7E-04)	9.1E-02* (3.8E-03)
$\zeta_c$					3.3E-05* (1.0E-06)
$\zeta_t$					-1.5E-04* (7.5E-05)
$\zeta_g$					2.6E-04 (1.7E-04)
Log-likelihood	1264.416	1264.416	1264.416	1267.393	1267.393

Emerging markets included are: Argentina, Brazil, Chile, China, Colombia, Egypt, India, Indonesia, South Korea, Mexico, Peru, Philippines, South Africa, Turkey

**Table 7** Panel GARCH model for developing countries: Sub-Saharan

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	4.5E-02* (8.7E-03)	4.2E-02* (9.1E-03)	4.1E-02* (9.2E-03)	4.9E-02* (8.8E-03)	1.9E-02* (7.2E-03)
$\beta_2$	2.1E-02* (6.9E-04)	1.6E-02* (1.6E-03)	1.8E-02* (1.1E-03)	3.0E-02* (2.9E-03)	-3.4E-03 (6.6E-03)
$\beta_3$	1.3E-02* (7.4E-03)	1.4E-02* (7.5E-03)	1.7E-02* (6.3E-03)	2.8E-02* (7.3E-03)	1.8E-03 (9.3E-03)
$\beta_4$	1.1E-02*	1.1E-02*	1.1E-02*	1.6E-02*	-2.1E-03

Table 7 continued

	(A)	(B)	(C)	(D)	(E)
	(3.4E-03)	(3.7E-03)	(5.4E-03)	(4.5E-03)	(5.3E-03)
$\beta_5$	1.1E-02 (1.2E-02)	6.1E-03 (1.3E-02)	1.5E-02 (1.2E-02)	2.6E-02* (1.1E-02)	-1.2E-02 (1.5E-02)
$\beta_6$	2.8E-02* (2.4E-03)	2.5E-02* (2.9E-03)	2.4E-02* (2.4E-03)	3.2E-02* (5.3E-03)	9.0E-03 (5.4E-03)
$\beta_7$	2.1E-02* (2.5E-03)	2.0E-02* (3.0E-03)	1.9E-02* (2.7E-03)	3.1E-02* (3.0E-03)	7.4E-03* (3.6E-03)
$\beta_8$	2.9E-02* (1.4E-03)	2.5E-02* (2.8E-03)	2.7E-02* (2.6E-03)	3.4E-02* (3.0E-03)	4.3E-03 (5.5E-03)
$\alpha$	4.4E-01* (2.4E-03)	4.5E-01* (2.5E-02)	4.6E-01* (2.1E-02)	4.1E-01* (2.5E-02)	4.4E-01* (3.4E-02)
$\kappa$		3.0E-02 (4.0E-02)	-3.2E-02 (2.9E-02)	-9.0E-03 (4.5E-02)	3.3E-01* (8.2E-02)
$\eta$				-2.0E-03* (3.4E-04)	-1.1E-04 (8.8E-04)
$\theta$				-1.3E-02 (1.0E-02)	-2.8E-03 (2.0E-02)
$\tau$				2.8E-02* (1.0E-02)	5.5E-02* (8.9E-03)
<i>Variance equation</i>					
$\delta$ (GARCH)	5.1E-01* (2.8E-04)	5.4E-01* (1.1E-03)	4.4E-01* (1.1E-02)	6.9E-01* (5.0E-03)	7.9E-01* (1.3E-04)
$\gamma$ (ARCH)	4.8E-01* (2.4E-02)	4.0E-01* (3.0E-02)	4.6E-01* (3.2E-02)	1.9E-01* (1.8E-02)	1.0E-01* (1.7E-03)
$\mu$			3.0E-03* (4.3E-05)	1.9E-03* (2.4E-05)	2.5E-03* (9.8E-05)
$\nu_c$					8.9E-05* (1.5E-07)
$\nu_t$					9.2E-04* (3.5E-04)
$\nu_g$					1.2E-04* (1.7E-05)
<i>Covariance equation</i>					
$\lambda$	-8.6E-01* (5.8E-03)	4.4E-01* (5.9E-03)	-7.4E-01* (3.7E-02)	6.6E-01* (2.1E-02)	8.0E-01* (1.1E-04)
$\rho$	-1.9E-03 (1.4E-03)	-7.6E-02 (4.3E-02)	5.5E-02* (2.2E-02)	-6.8E-02* (1.8E-02)	9.0E-02* (2.1E-03)
$\zeta_c$					1.1E-04* (1.4E-09)

**Table 7** continued

	(A)	(B)	(C)	(D)	(E)
$\zeta_t$					$-1.3E-03^*$ ( $3.7E-04$ )
$\zeta_g$					$4.1E-04^*$ ( $2.1E-05$ )
Log-likelihood	568.164	568.164	568.164	576.452	576.452

Countries included are Botswana, Cote d'Ivoire, Cameroon, Congo Rep., Gabon, Ghana, Kenya and Lesotho

**Table 8** Panel GARCH model for developing countries: South Asia

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	$3.1E-02^*$ ( $1.0E-03$ )	$4.4E-02^*$ ( $1.8E-03$ )	$3.6E-02^*$ ( $2.2E-04$ )	$3.9E-02^*$ ( $9.0E-04$ )	$3.5E-02^*$ ( $4.6E-04$ )
$\beta_2$	$2.5E-02^*$ ( $2.1E-03$ )	$5.5E-02^*$ ( $2.3E-02$ )	$3.3E-02^*$ ( $2.2E-03$ )	$4.4E-02^*$ ( $2.3E-03$ )	$3.8E-02^*$ ( $2.4E-04$ )
$\beta_3$	$2.7E-02^*$ ( $2.6E-03$ )	$5.8E-02$ ( $8.5E-02$ )	$3.5E-02^*$ ( $1.5E-03$ )	$4.7E-02^*$ ( $1.3E-03$ )	$4.2E-02^*$ ( $1.3E-04$ )
$\alpha$	$4.7E-01^*$ ( $1.9E-02$ )	$3.4E-01^*$ ( $5.0E-02$ )	$4.2E-01^*$ ( $4.0E-03$ )	$4.2E-01^*$ ( $1.6E-02$ )	$2.5E-01^*$ ( $3.5E-03$ )
$\kappa$		$-1.2E+00$ ( $3.5E+00$ )	$-3.5E-01^*$ ( $5.8E-02$ )	$-7.6E-01^*$ ( $5.6E-03$ )	$3.3E-02^*$ ( $7.0E-05$ )
$\eta$				$-4.6E-04^*$ ( $1.9E-04$ )	$-8.1E-04^*$ ( $2.9E-05$ )
$\theta$				$2.5E-02^*$ ( $7.9E-03$ )	$-1.5E-02^*$ ( $1.5E-03$ )
$\tau$				$2.0E-03$ ( $6.8E-03$ )	$2.9E-02^*$ ( $3.7E-04$ )
<i>Variance equation</i>					
$\delta$ (GARCH)	$8.8E-01^*$ ( $1.6E-03$ )	$8.9E-01^*$ ( $3.6E-03$ )	$7.8E-01^*$ ( $5.2E-06$ )	$7.6E-01^*$ ( $5.8E-03$ )	$6.6E-01^*$ ( $1.4E-05$ )
$\gamma$ (ARCH)	$3.9E-02^*$ ( $6.0E-03$ )	$8.5E-03^*$ ( $7.8E-04$ )	$8.7E-02^*$ ( $2.4E-03$ )	$7.2E-02^*$ ( $3.6E-04$ )	$9.1E-02^*$ ( $5.7E-04$ )
$\mu$			$-2.1E-04^*$ ( $4.1E-08$ )	$-2.6E-04^*$ ( $3.5E-05$ )	$4.4E-03^*$ ( $2.7E-07$ )
$\nu_c$					$-3.4E-05^*$ ( $5.1E-08$ )
$\nu_t$					$-6.8E-04^*$ ( $7.8E-06$ )
$\nu_g$					$-1.6E-04^*$ ( $3.5E-06$ )

**Table 8** continued

	(A)	(B)	(C)	(D)	(E)
<i>Covariance equation</i>					
$\lambda$	-7.1E-01* (1.5E-01)	-9.0E-01 (6.7E-01)	3.2E-01* (3.1E-02)	-6.0E-01* (3.2E-02)	7.8E-01* (6.6E-04)
$\rho$	9.4E-02* (3.0E-02)	6.8E-02 (5.3E-01)	6.8E-02* (1.1E-02)	1.7E-01* (1.8E-03)	3.4E-02* (6.9E-04)
$\zeta_c$					9.5E-07* (1.7E-07)
$\zeta_I$					-4.3E-04* (2.5E-05)
$\zeta_g$					5.5E-04* (1.4E-06)
Log-likelihood	301.156	301.156	301.156	302.601	302.601

Countries included Bangladesh, Pakistan and Sri Lanka

**Table 9** Panel GARCH model for developing countries: MENA

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	2.8E-02* (9.9E-04)	2.8E-02* (4.3E-04)	2.5E-02* (2.7E-03)	3.5E-02* (4.9E-04)	4.2E-02* (8.8E-05)
$\beta_2$	2.7E-02* (6.8E-05)	2.5E-02* (1.2E-03)	1.5E-02* (6.6E-03)	-1.8E-02* (2.6E-03)	-6.8E-03* (2.4E-04)
$\beta_3$	3.6E-02* (3.1E-04)	3.5E-02* (2.5E-03)	3.0E-02* (3.2E-03)	3.4E-02* (1.6E-03)	2.4E-02* (2.1E-05)
$\beta_4$	3.9E-02* (7.7E-04)	3.8E-02* (4.0E-03)	3.1E-02* (4.4E-03)	3.6E-02* (6.7E-03)	4.8E-02* (4.1E-05)
$\beta_5$	3.9E-02* (7.2E-05)	3.5E-02* (2.5E-04)	2.4E-02* (5.7E-03)	3.1E-02* (9.0E-04)	2.1E-02* (1.8E-04)
$\beta_6$	3.4E-02* (3.1E-05)	3.6E-02* (6.3E-04)	2.3E-02* (5.5E-03)	3.1E-02* (1.9E-03)	1.6E-02* (1.7E-04)
$\beta_7$	3.7E-02* (2.7E-04)	3.5E-02* (2.8E-03)	2.9E-02* (3.5E-03)	2.7E-02* (3.4E-05)	6.4E-03* (5.7E-05)
$\alpha$	1.3E-01* (2.5E-04)	1.3E-01* (3.4E-03)	1.2E-01* (3.6E-02)	7.1E-02* (3.8E-04)	1.2E-01* (2.2E-04)
$\kappa$		2.1E-02* (5.4E-03)	2.8E-01* (7.0E-02)	2.6E-01* (9.5E-04)	4.9E-02* (2.0E-04)
$\eta$				-2.5E-05* (6.8E-06)	4.5E-04* (8.1E-06)
$\theta$				4.4E-02* (4.5E-04)	4.0E-02* (3.6E-04)

**Table 9** continued

	(A)	(B)	(C)	(D)	(E)
$\tau$				3.0E-02* (1.1E-03)	5.2E-02* (8.0E-04)
<i>Variance equation</i>					
$\delta$ (GARCH)	7.6E-01* (7.8E-06)	7.2E-01* (8.2E-05)	6.6E-01* (4.1E-03)	8.5E-01* (5.7E-05)	8.1E-01* (7.4E-07)
$\gamma$ (ARCH)	1.1E-01* (1.2E-05)	1.2E-01* (1.7E-04)	1.8E-01* (2.9E-02)	8.8E-02* (6.5E-06)	1.1E-01* (3.3E-05)
$\mu$			1.1E-03* (3.4E-04)	-7.7E-05* (1.1E-06)	-1.8E-03* (1.6E-06)
$\nu_c$					5.1E-05* (2.0E-07)
$\nu_t$					-1.8E-03* (3.7E-05)
$\nu_g$					-9.9E-03* (2.4E-06)
<i>Covariance equation</i>					
$\lambda$	6.1E-01* (6.7E-06)	6.7E-01* (1.1E-04)	6.4E-01* (3.2E-03)	7.7E-01* (7.7E-05)	7.4E-01* (7.4E-06)
$\rho$	1.9E-02* (2.7E-05)	2.9E-03* (3.0E-04)	1.1E-02 (3.5E-02)	1.0E-01* (1.3E-05)	8.3E-02* (8.3E-05)
$\zeta_c$					-6.8E-06* (1.7E-07)
$\zeta_t$					1.7E-03* (3.0E-05)
$\zeta_g$					-4.1E-04* (1.3E-06)
Log-likelihood	521.454	521.454	521.454	513.830	513.830

Countries included are Algeria, Iran, Israel, Morocco, Oman, Saudi Arabia and Tunisia

**Table 10** Panel GARCH model for developing countries: Latin America and Caribbean

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	1.2E-02* (7.1E-05)	1.3E-02* (2.2E-06)	1.4E-02* (9.6E-04)	9.7E-03* (4.2E-04)	8.3E-03* (2.6E-03)
$\beta_2$	1.5E-02* (1.2E-05)	1.5E-02* (2.6E-03)	1.2E-02* (4.1E-05)	1.8E-02* (2.8E-04)	4.8E-03* (3.2E-03)
$\beta_3$	1.7E-02* (1.7E-03)	1.4E-02* (2.5E-04)	1.3E-02* (4.0E-03)	2.0E-02* (4.3E-03)	8.2E-03 (4.4E-03)

Table 10 continued

	(A)	(B)	(C)	(D)	(E)
$\beta_4$	1.7E-02* (2.6E-03)	1.7E-02* (3.5E-04)	1.7E-02* (2.6E-03)	1.1E-02* (3.1E-03)	1.1E-02* (3.9E-03)
$\beta_5$	5.1E-03* (5.3E-04)	4.8E-03* (1.3E-05)	4.5E-03* (2.9E-04)	6.3E-04 (2.0E-03)	-1.8E-03 (3.4E-03)
$\beta_6$	1.1E-02* (4.4E-04)	1.0E-02* (8.0E-04)	1.2E-02* (1.0E-05)	8.4E-03* (5.4E-04)	1.0E-02* (2.1E-03)
$\beta_7$	9.4E-03* (1.1E-04)	9.7E-03* (2.6E-03)	9.5E-03* (2.5E-03)	2.4E-03 (5.1E-03)	-6.3E-03 (5.3E-03)
$\beta_8$	6.1E-03* (4.6E-05)	6.7E-03* (8.0E-06)	6.2E-03* (5.1E-04)	7.8E-03* (2.3E-03)	4.7E-03 (4.6E-03)
$\beta_9$	3.1E-03* (2.0E-04)	3.1E-03* (7.7E-05)	2.9E-03* (5.7E-04)	-3.5E-03 (3.6E-03)	-9.9E-03* (4.7E-03)
$\beta_{10}$	7.5E-03* (1.8E-03)	7.5E-03* (1.3E-04)	7.5E-03* (3.2E-03)	2.3E-03 (8.1E-03)	-5.8E-03 (1.4E-02)
$\beta_{11}$	9.8E-03* (4.8E-03)	9.7E-03* (8.2E-05)	1.1E-02* (1.4E-03)	9.4E-03 (5.0E-03)	-3.5E-03 (4.8E-03)
$\beta_{12}$	1.2E-02* (3.7E-04)	1.2E-02* (2.2E-04)	1.2E-02* (4.5E-03)	9.0E-03* (3.8E-03)	-4.2E-03 (5.7E-03)
$\beta_{13}$	7.3E-03 (3.9E-03)	7.6E-03* (3.4E-03)	7.4E-03 (4.5E-03)	2.2E-03 (5.4E-03)	-1.0E-02 (8.4E-03)
$\alpha$	4.7E-01* (4.3E-05)	4.9E-01* (7.6E-06)	5.2E-01* (2.9E-04)	4.5E-01* (4.8E-03)	5.1E-01* (3.5E-02)
$\kappa$		5.4E-03* (1.6E-05)	4.7E-03* (4.8E-04)	2.0E-02* (6.2E-03)	3.7E-01* (6.5E-02)
$\eta$				2.0E-03* (6.9E-05)	-9.1E-04* (4.7E-04)
$\theta$				-1.6E-02* (5.8E-04)	-2.2E-02* (7.2E-03)
$\tau$				6.2E-03* (4.1E-04)	6.9E-03 (7.0E-03)
<i>Variance equation</i>					
$\delta$ (GARCH)	7.7E-01* (1.2E-05)	7.7E-01* (3.0E-06)	7.8E-01* (4.6E-05)	7.8E-01* (2.9E-05)	8.0E-01* (3.2E-05)
$\gamma$ (ARCH)	9.0E-02* (1.8E-05)	9.0E-02* (3.9E-06)	1.0E-01* (8.3E-05)	1.1E-01* (4.9E-04)	1.1E-01* (1.8E-03)
$\mu$			-2.2E-04* (1.0E-06)	-2.0E-04* (2.1E-06)	3.6E-04* (4.9E-05)
$\nu_c$					1.1E-05* (1.1E-06)

**Table 10** continued

	(A)	(B)	(C)	(D)	(E)
$\nu_t$					1.7E-04 (9.5E-05)
$\nu_g$					1.4E-05 (4.1E-05)
<i>Covariance equation</i>					
$\lambda$	8.8E-01* (6.4E-06)	8.6E-01* (5.4E-03)	8.6E-01* (4.2E-05)	8.5E-01* (9.5E-05)	7.8E-01* (2.4E-05)
$\rho$	-3.3E-02* (8.0E-06)	-3.1E-02* (4.5E-07)	-2.9E-02* (7.8E-05)	-2.5E-03* (4.2E-04)	8.4E-02* (1.1E-03)
$\zeta_c$					1.6E-05* (1.0E-06)
$\zeta_t$					-1.5E-04 (9.5E-05)
$\zeta_g$					-1.2E-04 (5.7E-05)
Log-likelihood	1184.819	1184.819	1184.819	1189.557	1189.557

Countries included are Bolivia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Nicaragua, Trinidad and Tobago, Uruguay and Venezuela

**Table 11** Panel GARCH model for developing countries: East Asia

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	2.1E-02* (6.3E-03)	1.8E-02* (2.6E-03)	2.1E-02* (4.1E-03)	8.2E-03 (2.1E-02)	-1.1E-04* (2.2E-05)
$\beta_2$	5.5E-02* (2.9E-03)	5.1E-02 (5.0E-02)	5.4E-02* (1.6E-05)	3.8E-02* (1.5E-03)	6.9E-03* (1.9E-06)
$\beta_3$	5.8E-02* (3.2E-03)	6.1E-02 (5.1E-02)	6.4E-02* (2.2E-05)	4.0E-02* (2.1E-03)	7.2E-03* (4.5E-06)
$\beta_4$	5.2E-02* (3.4E-03)	4.7E-02* (6.5E-05)	5.0E-02* (3.0E-03)	3.2E-02* (3.1E-03)	3.7E-03* (5.6E-06)
$\alpha$	1.1E-01* (3.4E-02)	1.1E-01* (4.8E-06)	8.7E-02* (1.1E-04)	1.5E-01* (4.1E-02)	1.4E-01* (2.0E-05)
$\kappa$		1.2E-02* (1.3E-05)	-8.6E-04* (2.5E-04)	3.8E-02 (1.1E-01)	3.0E-03* (2.8E-05)
$\eta$				2.9E-03* (8.6E-04)	3.9E-04* (1.0E-06)
$\theta$				-3.5E-02* (7.5E-03)	-2.7E-02* (2.7E-05)
$\tau$				2.4E-02* (1.1E-02)	3.3E-02* (3.7E-05)



**Table 11** continued

	(A)	(B)	(C)	(D)	(E)
<i>Variance equation</i>					
$\delta$ (GARCH)	8.5E-01* (1.7E-03)	8.1E-01* (1.8E-06)	8.1E-01* (1.7E-05)	8.0E-01* (1.2E-03)	7.9E-01* (8.2E-07)
$\gamma$ (ARCH)	-6.8E-02* (4.4E-03)	5.4E-02* (2.9E-06)	7.7E-02* (4.2E-05)	8.7E-02* (1.2E-03)	9.9E-02* (7.9E-07)
$\mu$			6.8E-04* (9.4E-07)	5.8E-04* (2.1E-06)	3.2E-04* (4.4E-07)
$\nu_c$					7.4E-05* (2.2E-07)
$\nu_t$					-6.7E-04* (3.8E-07)
$\nu_g$					-3.6E-04* (4.6E-07)
<i>Covariance equation</i>					
$\lambda$	9.3E-01* (1.6E-03)	8.4E-01* (9.6E-02)	8.6E-01* (1.7E-05)	8.0E-01* (1.6E-03)	8.1E-01* (3.0E-03)
$\rho$	-6.6E-02* (2.7E-03)	-2.4E-02* (8.5E-07)	-8.9E-03* (4.1E-05)	1.1E-01* (1.3E-03)	9.6E-02* (2.7E-03)
$\zeta_c$					5.0E-05* (2.6E-06)
$\zeta_t$					4.9E-04* (2.0E-04)
$\zeta_g$					-2.1E-05 (6.1E-05)
Log-likelihood	348.447	348.447	348.447	349.347	349.347

Countries included are Fiji, Malaysia, Singapore and Thailand

**Table 12** Panel GARCH model for least developed countries

	(A)	(B)	(C)	(D)	(E)
<i>Mean equation</i>					
$\beta_1$	4.0E-02* (3.2E-03)	4.5E-02* (2.5E-03)	4.0E-02* (2.7E-03)	2.2E-02* (3.1E-03)	4.0E-04 (6.1E-03)
$\beta_2$	4.7E-02* (2.6E-03)	4.4E-02* (2.1E-03)	3.6E-02* (2.0E-03)	2.7E-02* (2.1E-03)	9.3E-04 (7.7E-03)
$\beta_3$	2.4E-02* (3.1E-03)	2.2E-02* (4.9E-03)	2.3E-02* (5.6E-03)	6.0E-03 (5.1E-03)	2.7E-05 (8.4E-03)
$\beta_4$	-7.9E-03 (5.3E-03)	1.3E-03* (6.4E-03)	-2.0E-03 (6.5E-03)	-1.6E-02 (1.6E-02)	-4.5E-04 (8.8E-03)

Table 12 continued

	(A)	(B)	(C)	(D)	(E)
$\beta_5$	3.6E-02* (1.5E-02)	3.0E-02* (1.4E-02)	3.2E-02* (1.6E-02)	6.7E-03 (1.2E-02)	2.3E-04 (1.5E-02)
$\beta_6$	1.7E-02* (4.6E-03)	1.1E-02* (3.7E-03)	8.6E-03 (4.7E-03)	-9.8E-03* (3.7E-03)	-2.0E-04 (6.7E-03)
$\beta_7$	4.3E-02* (4.0E-03)	3.6E-02* (5.7E-03)	3.1E-02* (3.8E-03)	2.1E-02* (5.3E-03)	6.5E-04 (8.0E-03)
$\beta_8$	5.4E-02* (5.8E-03)	5.4E-02* (5.9E-03)	3.5E-02* (4.7E-03)	2.8E-02* (7.3E-03)	2.6E-04 (1.1E-02)
$\beta_9$	3.3E-02* (5.5E-03)	2.7E-02* (5.2E-03)	2.1E-02* (5.5E-03)	5.9E-03 (6.3E-03)	7.2E-05 (9.2E-03)
$\beta_{10}$	2.7E-02* (6.1E-03)	1.8E-02* (5.7E-03)	4.8E-03 (4.8E-03)	-4.8E-03 (6.7E-03)	-5.1E-04 (9.7E-03)
$\beta_{11}$	3.3E-02* (1.5E-02)	1.6E-02 (1.3E-02)	-2.2E-03 (8.2E-03)	1.5E-02 (1.2E-02)	-8.0E-05 (1.3E-02)
$\beta_{12}$	3.0E-02* (2.5E-03)	2.8E-02* (2.9E-03)	2.0E-02* (2.8E-03)	1.4E-02* (3.1E-03)	7.5E-05 (5.7E-03)
$\beta_{13}$	3.4E-02* (7.7E-03)	3.1E-02* (8.9E-03)	3.5E-02* (9.2E-03)	7.6E-03 (8.3E-03)	-1.8E-04 (1.5E-02)
$\beta_{14}$	4.1E-02* (4.2E-03)	2.6E-02* (3.6E-03)	3.4E-02* (4.7E-03)	1.6E-02* (6.9E-03)	1.1E-03 (1.2E-02)
$\beta_{15}$	3.2E-02* (1.2E-02)	3.1E-02* (8.8E-03)	3.2E-02* (1.0E-02)	1.0E-02 (7.0E-03)	2.9E-04 (1.0E-02)
$\alpha$	2.8E-02 (1.7E-02)	3.0E-02 (1.9E-02)	3.1E-02 (1.7E-02)	5.8E-02* (2.9E-02)	3.1E-02 (6.3E-02)
$\kappa$		3.6E-02 (3.1E-02)	1.8E-02 (2.6E-02)	1.1E-01* (3.6E-02)	1.0E-02 (6.5E-02)
$\eta$				2.2E-03* (3.4E-04)	-5.5E-03* (7.8E-04)
$\theta$				1.9E-02* (9.8E-03)	8.7E-03 (1.2E-02)
$\tau$				4.3E-02* (8.8E-03)	4.6E-02* (8.6E-03)
<i>Variance equation</i>					
$\delta$ (GARCH)	8.1E-01* (4.6E-03)	8.1E-01* (3.8E-03)	8.8E-01* (8.0E-04)	8.4E-01* (6.0E-05)	8.2E-01* (9.1E-04)
$\gamma$ (ARCH)	5.7E-02* (6.9E-03)	5.8E-02* (6.4E-03)	3.3E-02* (3.9E-03)	9.9E-02* (4.6E-03)	1.0E-01* (2.6E-03)
$\mu$			-8.4E-04* (1.4E-04)	-1.7E-03* (5.6E-05)	3.5E-05 (3.7E-04)

Table 12 continued

	(A)	(B)	(C)	(D)	(E)
$\nu_c$					6.9E-05* (2.4E-06)
$\nu_t$					-2.7E-04 (3.0E-04)
$\nu_g$					1.3E-03* (3.2E-04)
<i>Covariance equation</i>					
$\lambda$	8.7E-01* (3.7E-03)	8.9E-01* (4.3E-04)	9.3E-01* (9.9E-05)	7.7E-01* (4.0E-06)	8.0E-01* (8.3E-04)
$\rho$	-4.2E-02* (3.6E-03)	-3.8E-02* (3.8E-03)	-4.3E-02* (3.3E-03)	5.2E-02* (1.0E-02)	9.2E-02* (3.0E-03)
$\zeta_c$					7.4E-05* (3.9E-08)
$\zeta_t$					4.8E-04 (2.9E-04)
$\zeta_g$					3.1E-04 (3.2E-04)
Log-likelihood	1049.499	1049.499	1049.499	1062.011	1062.011

Countries used are Benin, Burkina Faso, Burundi, Central African Republic, Chad, Madagascar, Malawi, Mali, Mauritania, Niger, Rwanda, Senegal, Sierra Leone, Sudan and Togo

## References

- Acemoglu D (2010) Institutions, factor prices, and taxation: virtues of strong states? *Am Econ Rev* 100(2):115–19
- Acemoglu D, Robinson J (2010) The role of institutions in growth and development. *Leadersh Growth* 1:135
- Acemoglu D, Johnson S, Robinson J, Thaicharoen Y (2003) Institutional causes, macroeconomic symptoms: volatility, crises and growth. *J Monet Econ* 50(1):49–123
- Acemoglu D, Johnson S, Robinson JA (2005) Institutions as a fundamental cause of long-run growth. *Handb Econ Growth* 1:385–472
- Aisen A, Veiga FJ (2013) How does political instability affect economic growth? *Eur J Polit Econ* 29:151–167
- Alimi N (2016) Volatility and growth in developing countries: an asymmetric effect. *J Econ Asymmet* 14:179–188
- Antonakakis N, Badinger H (2016) Economic growth, volatility, and cross-country spillovers: new evidence for the G7 countries. *Econ Model* 52:352–365
- Barro RJ (1996) Democracy and growth. *J Econ Growth* 1(1):1–27
- Barro RJ (2013) Democracy, law and order, and economic growth. *Index Econ Freedom* 2013:41–58
- Bassanini A, Scarpetta S (2002) The driving forces of economic growth. *OECD Econ Stud* 2001(2):9–56
- Bernanke BS (1983) Irreversibility, uncertainty, and cyclical investment. *Q J Econ* 98(1):85–106
- Black F (1987) *Business cycles and equilibrium*. Basil Blackwell, New York
- Blackburn K (1999) Can stabilisation policy reduce long-run growth? *Econ J* 109(452):67–77
- Blackburn K, Galindez R (2003) Growth, volatility and learning. *Econ Lett* 79(3):417–421
- Blackburn K, Pelloni A (2004) On the relationship between growth and volatility. *Econ Lett* 83(1):123–127
- Blackburn K, Pelloni A (2005) Growth, cycles, and stabilization policy. *Oxf Econ Pap* 57(2):262–282

- Caporale T, McKiernan B (1996) The relationship between output variability and growth: evidence from post war UK data. *Scott J Polit Econ* 43(2):229–236
- Caporale T, McKiernan B (1998) The Fischer Black hypothesis: some time-series evidence. *South Econ J* 64(3):765–771
- Cermeño R, Grier KB (2006) Conditional heteroskedasticity and cross-sectional dependence in panel data: an empirical study of inflation uncertainty in the G7 countries. In: Baltagi BH (ed) *Contributions to economic analysis*. Elsevier, Berlin, pp 259–277 (**Chapter 10**)
- Cermeño R, Sanin ME (2015) Are flexible exchange rate regimes more volatile? Panel (GARCH) evidence for the G7 and Latin America. *Rev Dev Econ* 19(2):297–308
- Dawson JW (1998) Institutions, investment, and growth: new cross-country and panel data evidence. *Econ Inq* 36(4):603–619
- Easterly W, Ritzen J, Woolcock M (2006) Social cohesion, institutions, and growth. *Econ Polit* 18(2):103–120
- Edwards S (1998) Openness, productivity and growth: what do we really know? *Econ J* 108(447):383–398
- Esfahani HS, Ramirez MT (2003) Institutions, infrastructure, and economic growth. *J Dev Econ* 70(2):443–477
- Falvey R, Foster N, Greenaway D (2012) Trade liberalization, economic crises, and growth. *World Dev* 40(11):2177–2193
- Fountas S, Karanasos M (2006) The relationship between economic growth and real uncertainty in the G3. *Econ Model* 23(4):638–647
- Fountas S, Karanasos M, Kim J (2002) Inflation and output growth uncertainty and their relationship with inflation and output growth. *Econ Lett* 75(3):293–301
- Fountas S, Karanasos M, Mendoza A (2004) Output variability and economic growth: the Japanese case. *Bull Econ Res* 56(4):353–363
- Friedman M (1968) The role of monetary policy. *Am Econ Rev* 58(1):1–17
- Friedman M (1977) Nobel lecture: inflation and unemployment. *J Polit Econ* 85(3):451–472
- Grier KB, Perry MJ (2000) The effects of real and nominal uncertainty on inflation and output growth: some GARCH-M evidence. *J Appl Econom* 15(1):45–58
- Grier KB, Tullock G (1989) An empirical analysis of cross-national economic growth, 1951–1980. *J Monet Econ* 24(2):259–276
- Grier KB, Henry ÓT, Olekalns N, Shields K (2004) The asymmetric effects of uncertainty on inflation and output growth. *J Appl Econom* 19(5):551–565
- Grinols EL, Turnovsky SJ (1998) Risk, optimal government finance and monetary policies in a growing economy. *Economica* 65(259):401–427
- Grossman GM, Helpman E (1990) Comparative advantage and long-run growth. *Am Econ Rev* 80(4):796–815
- Henry OT, Olekalns N (2002) The effect of recessions on the relationship between output variability and growth. *South Econ J* 68(3):683–692
- Hnatkowska V, Loayza N (2004) *Volatility and growth*. World Bank Publications, Singapore
- Imbs J (2007) Growth and volatility. *J Monet Econ* 54(7):1848–1862
- Karam F, Zaki C (2015) Trade volume and economic growth in the MENA region: goods or services? *Econ Model* 45:22–37
- Karras G (2006) Trade openness, economic size, and macroeconomic volatility: theory and empirical evidence. *J Econ Integr* 21(2):254–272
- Keynes J (1936) *The general theory of employment, interest, and money*. Macmillan, London
- Kim D-H, Lin S-C, Suen Y-B (2016) Trade, growth and growth volatility: new panel evidence. *Int Rev Econ Finance* 45:384–399
- King RG, Plosser CI, Rebelo ST (1988) Production, growth and business cycles: II. New directions. *J Monet Econ* 21(2–3):309–341
- Kneller R, Young G (2001) Business cycle volatility, uncertainty and long-run growth. *Manch Sch* 69(5):534–552
- Kormendi RC, Meguire PG (1985) Macroeconomic determinants of growth: cross-country evidence. *J Monet Econ* 16(2):141–163
- Kose MA, Prasad ES, Terrones ME (2003) Financial integration and macroeconomic volatility. *IMF Staff Pap* 50(Special Issue):119–142
- Kydland FE, Prescott EC (1982) Time to build and aggregate fluctuations. *Econometrica* 50(6):1345–1370

- Lee J (2010) The link between output growth and volatility: evidence from a GARCH model with panel data. *Econ Lett* 106(2):143–145
- Lee J, Valera HGA (2016) Price transmission and volatility spillovers in (A)sian rice markets: evidence from MGARCH and panel GARCH models. *Int Trade J* 30(1):14–32
- Lee HY, Ricci LA, Rigobon R (2004) Once again, is openness good for growth? *J Dev Econ* 75(2):451–472
- Long JB Jr, Plosser CI (1983) Real business cycles. *J Polit Econ* 91(1):39–69
- Mirman LJ (1971) Uncertainty and optimal consumption decisions. *Econometrica* 39(1):179–185
- Nawaz S (2015) Growth effects of institutions: a disaggregated analysis. *Econ Model* 45:118–126
- Pindyck RS (1990) Irreversibility, uncertainty, and investment. Technical report, National Bureau of Economic Research
- Ramey G, Ramey VA (1995) Cross-country evidence on the link between volatility and growth. *Am Econ Rev* 85(5):1138–1151
- Razin A, Rose A (1992) Business cycle volatility and openness: an exploratory cross-section analysis. Technical report, National Bureau of Economic Research
- Ribeiro PP, Cermeño R, Curto JD (2017) Sovereign bond markets and financial volatility dynamics: panel-GARCH evidence for six Euro area countries. *Finance Res Lett* 21:107–114
- Rodriguez F, Rodrik D (2000) Trade policy and economic growth: a skeptic's guide to the cross-national evidence. *NBER Macroecon Ann* 15:261–325
- Rodrik D, Subramanian A, Trebbi F (2004) Institutions rule: the primacy of institutions over geography and integration in economic development. *J Econ Growth* 9(2):131–165
- Romer PM (1990) Endogenous technological change. *J Polit Econ* 98(5, Part 2):S71–S102
- Sachs JD, Warner A, Åslund A, Fischer S (1995) Economic reform and the process of global integration. *Brook Pap Econ Act* 1995(1):1–118
- Salton A, Ely RA (2017) Uncertainty and growth: evidence of emerging and developed countries. *Econ Bull* 37(2):1274–1280
- Sandmo A (1970) The effect of uncertainty on saving decisions. *Rev Econ Stud* 37(3):353–360
- Schularick M, Solomou S (2011) Tariffs and economic growth in the first era of globalization. *J Econ Growth* 16(1):33–70
- Speight AE (1999) (UK) output variability and growth: some further evidence. *Scott J Polit Econ* 46(2):175–184
- Taylor JB (1979) Estimation and control of a macroeconomic model with rational expectations. *Econometrica* 47(5):1267–1286
- Trypsteen S (2017) The growth-volatility nexus: new evidence from an augmented GARCH-M model. *Econ Model* 63:15–25
- Tsouma E (2014) The link between output growth and real uncertainty in Greece: a tool to speed up economic recovery? *Theor Econ Lett* 4(1):91–97
- Turnovsky SJ (2000) Government policy in a stochastic growth model with elastic labor supply. *J Public Econ Theory* 2(4):389–433
- Turnovsky SJ, Chattopadhyay P (2003) Volatility and growth in developing economies: some numerical results and empirical evidence. *J Int Econ* 59(2):267–295
- Valera HGA, Holmes MJ, Hassan G (2017a) Stock market uncertainty and interest rate behaviour: a panel GARCH approach. *Appl Econ Lett* 24(11):732–735
- Valera HGA, Holmes MJ, Hassan GM (2017b) Is inflation targeting credible in Asia? A panel GARCH approach. *Empir Econ* 54:1–24
- Young A (1991) Learning by doing and the dynamic effects of international trade. *Q J Econ* 106(2):369–405
- Zarnowitz V, Moore GH (1986) Major changes in cyclical behavior. In: Gordon RJ (ed) *The American business cycle: continuity and change*. University of Chicago Press, Chicago, pp 519–582