Revisiting the link between Growth and Volatility: Panel GARCH analysis

Pinar Deniz[*], Thanasis Stengos[†], Ege Yazgan[‡]

Abstract: This paper explores the link between output growth and volatility using several macroeconomic variables for a panel of countries for the period of 1970-2014. 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.

Keywords: Growth, Volatility, Panel GARCH–M model

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[*]Department of Economics, Marmara University, Turkey, E-mail: pinar.deniz@marmara.edu.tr

[†]Department of Economics, University of Guelph, Canada, E-mail: tstengos@uoguelph.ca

[‡]Department of Economics, Istanbul Bilgi University, Turkey, E-mail: ege.yazgan@bilgi.edu.tr

1. Introduction

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 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.

Volatility processes are typically examined using GARCH-type models, however mostly using a single country approach. In this study, we employ a panel data model following 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. The main advantage of this methodology 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. Empirical studies using the simpler version of the panel GARCH in mean model have recently appeared in the literature (Lee and Valera, 2016; Valera et al., 2017a, 2017b) yet, panel dynamic GARCH-M models with lagged dependent in the conditional variance model as well are only a few (Lee, 2010; Cermeo and Sanin, 2015; Ribeiro et al. 2017).

The literature for the link between output growth and its volatility within a GARCH framework is limited. Lee (2010), employing a panel GARCH model, observed a positive impact of volatility on growth whereas the inverse link is found to be insignificant for the period of 1965–2007 for G7 countries; 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 7 emerging and 7 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; and Tsouma (2014) examines the link for Greece economy using GARCH–M and finds negative relationship both ways.

However, all the above papers do not produce any additional regressors beyond our lags in the GARCH–M specification. To the best of our knowledge, this is the first panel GARCH–M analysis that incorporates independent variables in 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 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 theoretical framework and covers the 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. Theoretical and Empirical Literature

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 is the one that was prevalent in the early literature, where the connection between business cycle theory and economic growth did not consider that link (Kydland and Prescott, 1982; Long and Plosser, 1983; and 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).

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 third 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 will result in higher growth within the framework of neoclassical growth theory (Sandmo, 1970; and Mirman, 1971); and the reward mechanism of taking higher risk (Black, 1987).

There is also no theoretical consensus regarding the impact of output growth on output volatility, even though this causal link is not investigated in the literature as wide as its opposite counterpart.

The theoretical negative link is 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.

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.

The link between output growth and output volatility is found 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 Galinder (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), Grier and Tullock (1989) using cross country analysis, Caporale and McKiernan (1998), 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), Henry and Olekalns (2002) for US data, Ramey and Ramey (1995), Kneller and Young (2001) using a panel data, Hantkovska 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). As for the two-way relationship, Fountas and Karanasos (2006) find a positive effect of volatility on growth but negative effect of growth on volatility, using a GARCH-M model for 3 developed countries; Lee (2010) also finds positive effect of volatility on growth for 7 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.

3. The Model and data

3.1 Data

This study employs annual data for the period of 1970-2014 for 82 countries divided into several country groups based on their development level and region.

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 to 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.

Table 1: Descriptive Statistics

	y	CL	GOV	TO	y	CL	GOV	TO
	Developed EU				**Developed Non-EU**			
Mean	0.03	1.30	0.01	0.01	0.03	1.12	0.01	0.02
Maximum	0.13	6.00	0.30	0.25	0.08	2.00	0.16	0.39
Minimum	-0.08	1.00	-0.10	-0.23	-0.06	1.00	-0.05	-0.29
Std. Dev.	0.03	0.73	0.04	0.06	0.02	0.33	0.03	0.08
Skewness	-0.14	4.15	1.36	-0.05	-0.68	2.31	1.31	0.13
Kurtosis	4.73	24.99	10.16	4.39	4.36	6.32	6.13	7.68
Jarque-Bera	81.04	14494.45	1541.46	50.75	27.93	242.35	124.57	164.75
Observations	630	630	630	630	180	180	180	180
	Emerging				**Sub-Saharan**			
Mean	0.05	3.81	0.01	0.03	0.05	4.50	0.01	0.02
Maximum	0.19	7.00	3.54	0.91	0.40	7.00	0.85	0.83
Minimum	-0.13	1.00	-0.30	-0.41	-0.24	2.00	-0.41	-0.43
Std. Dev.	0.04	1.42	0.16	0.13	0.06	1.34	0.15	0.14
Skewness	-0.73	0.24	15.97	1.78	0.77	-0.36	1.49	1.55
Kurtosis	5.08	2.25	343.17	12.34	8.69	2.13	8.56	10.28
Jarque-Bera	170.60	20.95	3064282.00	2623.11	520.47	19.05	596.48	938.15
Observations	630	630	630	630	360	360	360	360
	South Asia				**MENA**			
Mean	0.05	4.29	0.00	0.02	0.04	5.04	0.02	0.01
Maximum	0.11	5.00	0.33	1.04	0.27	7.00	1.52	0.51
Minimum	-0.14	2.00	-0.52	-0.24	-0.22	2.00	-0.40	-1.00
Std. Dev.	0.03	0.73	0.12	0.13	0.06	1.36	0.15	0.12
Skewness	-2.48	-0.62	-0.72	3.49	0.16	-0.83	4.34	-1.44
Kurtosis	16.34	2.51	7.20	26.54	6.73	3.01	40.80	18.58
Jarque-Bera	1139.50	10.01	110.78	3392.02	183.08	36.16	19675.74	3286.20
Observations	135	135	135	135	314	314	314	314
	Latin America				**East Asia**			
Mean	0.03	2.93	0.01	0.02	0.06	3.91	0.00	0.02
Maximum	0.18	7.00	1.70	1.99	0.15	6.00	0.26	0.28
Minimum	-0.27	1.00	-0.57	-0.43	-0.08	2.00	-0.19	-0.18
Std. Dev.	0.04	1.13	0.14	0.15	0.04	0.94	0.08	0.08
Skewness	-0.89	0.43	3.36	4.47	-0.66	-0.45	0.32	0.46
Kurtosis	7.74	3.20	38.89	53.03	3.33	2.43	3.36	3.63
Jarque-Bera	624.24	19.11	32505.87	62957.97	13.97	8.55	4.02	9.49
Observations	585	585	585	585	180	180	180	180
	Least Developed							
Mean	0.03	5.04	0.02	0.02				
Maximum	0.35	7.00	1.42	1.77				
Minimum	-0.50	2.00	-0.46	-0.56				
Std. Dev.	0.06	1.34	0.17	0.18				
Skewness	-1.12	-0.43	1.98	2.43				
Kurtosis	15.97	2.38	12.89	20.32				
Jarque-Bera	4870.24	32.03	3192.38	9105.11				
Observations	675	675	675	675				

Note: The data covers the period 1970-2014. GOV and TO variables are expressed in first differences.

Figure 1 shows the volatility of GDP growth rates for different country groups calculated as 15-year non-overlapping standard deviations. The figure[1] 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.

[1] All countries in World Bank database having GDP growth rates available are included.

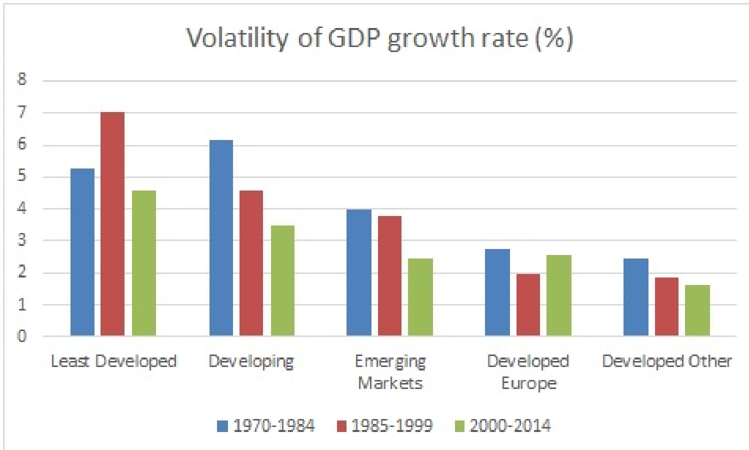

Figure 1: Volatility of GDP growth rate (%)
Notes: Standard deviation measurement is used for volatility.

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.

$$y_{i,t} = \beta + \alpha y_{i,t-1} + \kappa\sigma_{i,t} + \eta CL_{i,t} + \theta GOV_{i,t} + \tau TO_{i,t} + \epsilon_{i,t} \tag{1}$$

where N is the number of cross sections and T is the time periods; β is the intercept and α is the autoregressive coefficient[2]; η, θ and τ are the coefficients of the independent variables and $\epsilon_{i,t}$ is the disturbance error with zero mean and normal distribution and the conditional moments given in Equations (2) to (5):[3]

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

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

$$E[\epsilon_{i,t}\epsilon_{j,s}] = \sigma^2_{ijt} \qquad \text{for} \quad i{\neq}j \text{ and t=s} \tag{4}$$

$$E[\epsilon_{i,t}\epsilon_{j,s}] = \sigma^2_{it} \qquad \text{for} \quad i{=}j \text{ and t=s} \tag{5}$$

[2]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.

[3]Equation (2) assumes no contemporaneous cross-sectional correlation; Equation (3) assumes no autocorrelation; Equations (4) and (5) are the assumptions for the conditions of the conditional variance-covariance process.

Following the model of Cermeño and Grier (2006), the conditional variance and covariance processes of output are defined in Equations (6) and (7), successively. We assume GARCH(1,1) process for conditional variance and covariance equation taking into account the literature.

$$\sigma_{i,t}^2 = \phi_i + \delta\sigma_{i,t-1}^2 + \gamma\epsilon_{i,t-1}^2 + \mu y_{i,t-1} + \nu_c CL_{i,t} + \nu_t TO_{i,t} + \nu_g GOV_{i,t} \quad (6)$$

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

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

$$y_t = \beta + Z_t\theta + \epsilon_t, \qquad t = 1, ...T \quad (8)$$

where Z_t is a matrix with lagged dependent variable and independent variables. The error term has a multivariate normal distribution $N(0, \Omega_t)$. The log-likelihood function for the complete panel is as follows:

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

The panel GARCH model is estimated via maximum likelihood (ML) method that maximizes above equation.

4. Empirical Results

Tables 3 to 9 present the estimation results for three 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 variables to the conditional equations. Models 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. We used World Bank country regional classification for country groups[4].

Table 2 shows the Panel GARCH estimation results for 14 developed EU countries in the 5 different models. It is observed that for developed EU countries, the impact of volatility on growth, κ, turns out to be insignificant, whereas the impact of growth on volatility, μ, is positive. This result suggests that higher

[4] Country information are available in the notes under the tables.

growth is more volatile, implying that higher growth becomes less predictable[5]. The institutional variable is observed to have a positive impact on growth but negative on volatility. Note that a rise in the institutional variable refers to a decline in institutional quality.Trade openness is observed to be contributing to growth rate, whereas government expenditure affects it in a negative way, consistent with neoclassical theory that a rise in government expenditure is likely to increase interest rates which will further lower output growth in a dynamic setting.

Developed Non-EU countries, given in Table 3, reveal no significant coefficient for κ and a negative coefficient for μ, which is in contrast with the GARCH model without independent variables. The institutional variable is observed to be negatively affecting growth rate, suggesting that the better the institutional quality, the higher the growth rate will be. Government expenditure, similar to developed EU countries, affects growth rate negatively, whereas its impact on volatility is positive. Trade openness is also observed to be positively affecting volatility.

Tables 4 and 10 provide the findings for the least developed and emerging countries respectively. Tables 5 to 9 provide panel GARCH results for developing countries divided into regions as SubSaharan, South Asia, Middle East and North Africa (MENA), Latin America and Caribbean and East Asia and Pacific. For emerging markets, given in Table 4, κ is found to be insignificant, whereas μ is positive meaning that growth rate rises volatility. Institutional quality is observed to be affecting both growth and its volatility negatively. Government expenditure and trade openness variables are also found to be negatively affecting growth rate. Table 5, for the Subsaharan countries reveal positive bi-directional relationship between growth and volatility. Institutional quality contributes to both growth and volatility, whereas trade openness is found to be increasing volatility. South Asia, MENA and least developed countries show a significant relationship between growth and volatility, as given in Tables 6, 7 and 10, whereas Latin American and East Asian countries reveal a negative link from volatility to growth but no significant impact from growth to volatility, see Tables 8 and 9. Institutional quality is observed to be raising volatility except for MENA; contributory to growth for Latin American and least developed countries, whereas it the opposite result for MENA and East Asian countries. Trade openness contributes to South Asian growth and lowers volatility, whereas the findings are reverse for East Asian countries.

As a generalization, country groups either reveal negative (6 out of 9 groups) or insignificant coefficient for the impact of government expenditure on growth, θ signaling the distortionary effect of government expenditure on output growth. Secondly, the impact of volatility on growth, κ is found to be negative for two developing country groups, namely for Latin America and East Asia and it is insignificant for the rest of the 7 country groups. The negative link seems to be in line with the early theoretical study of Pindyck (1990), who argues that instability may have a depressing effect on investment for developing countries.

[5]See for example the results of Cermeño and Grier (2006).

Another remarkable finding is the positive coefficient of the institutional variable on volatility, η_c for 5 developing and emerging country groups out of 7 (except for Subsaharan and MENA countries, where the lack of significance can be attributed to having different economic and political structures than the rest of developing countries, being oil-based and politically dependent on the US for example), something that signifies the negative impact of institutional quality on economic volatility. This finding plus Figure 1 seems to be consistent with the findings of Acemoglu et al. (2003) in the way that countries which inherit bad institutions from European colonial powers happen to experience higher economic volatility. Another finding to highlight is the autoregressive coefficients of the mean equation, α, which turns out to be the lowest and even insignificant for the least developed countries whereas it provides high and very close values for other country groups which signifies that the persistence of growth rate is lowest for least developed countries as it can be expected due to their nonstable economic patterns.

Last of all, we find that the results do change with the inclusion of independent variables as seen in model E compared to model C for κ and μ, something that highlights the usefulness of our approach. 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 seen in the last row of table and offer an improvement over the other simpler specifications.

5. Conclusion

This paper focuses on the relationship between output growth and its volatility using 82 countries divided into country groups for the period 1970-2014. 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. As a generalization, institutional quality appears to have negative impact on volatility for developing and emerging countries, whereas government expenditure is found to have negative impact on output growth.

Table 2: Panel GARCH Model for Developed EU Countries

	(A)	(B)	(C)	(D)	(E)
Mean Equation					
β	0.014*	0.014*	0.015*	0.012*	0.013*
	(0.001)	(1.8E-04)	(0.001)	(0.001)	(0.001)
α	0.405*	0.399*	0.407*	0.393*	0.401*
	(0.032)	(0.005)	(0.031)	(0.038)	(0.040)
κ		0.002*	-0.051	-0.050	-0.014
		(0.007)	(0.061)	(0.065)	(0.066)
η				0.002*	0.002*
				(0.001)	(0.001)
τ				0.011*	0.016*
				(0.007)	(0.009)
θ				-0.193*	-0.242*
				(0.014)	(0.012)
Variance Equation					
δ**(GARCH)**	0.794*	0.795*	0.797*	0.798*	0.804*
	(0.001)	(7.4E-05)	(0.002)	(2.5E-04)	(0.002)
γ**(ARCH)**	0.092*	0.095*	0.093*	0.093*	0.102*
	(0.004)	(1.6E-04)	(0.003)	(0.001)	(0.003)
μ			2.9E-05*	2.7E-05*	6.5E-05*
			(1.3E-05)	(3.8E-06)	(2.0E-05)
ν_t					-2.8E-05
					(3.5E-05)
ν_c					-1.7E-06*
					(1.4E-07)
ν_g					5.5E-05
					(4.4E-05)
Covariance Equation					
λ	0.815*	0.818*	0.789*	0.799*	0.783*
	(0.001)	(6.7E-05)	(0.002)	(4.2E-06)	(4.4E-04)
ρ	0.040*	0.041*	0.059*	0.054*	0.083*
	(0.003)	(1.5E-04)	(0.003)	(0.001)	(0.003)
ζ_c					-4.4E-07
					(3.5E-07)
ζ_t					4.9E-05
					(3.3E-05)
ζ_g					3.2E-05
					(4.1E-05)
Log-likelihood	1745.6526	1745.6526	1745.6526	1804.4016	1804.4016

Note: Standard errors are given in paranthesis. (*) indicate significance at 10%. (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). All the parameters were estimated simultaneously by maximum likelihood. Selected countries are Austria, Belgium, Denmark, Finland, France, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom. ϕ_i and φ_{ij} are not presented to save space but can be provided on demand. N= 14, T=1970-2014. The analysis is done both for homogeneous (β) and heterogeneous constant coefficients (β_i) both of which bring same results.

Table 3: Panel GARCH Model for Developed Non-EU Countries

	(A)	**(B)**	**(C)**	**(D)**	**(E)**
Mean Equation					
β	0.025*	0.035*	0.032*	0.036*	0.035*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
α	0.196*	0.266*	0.246*	0.234*	0.198*
	(0.008)	(0.005)	(0.035)	(0.016)	(0.032)
κ		-0.765*	-0.558*	-0.345*	0.013
		(0.065)	(0.088)	(0.025)	(0.145)
η				-0.007*	-0.009*
				(0.000)	(0.002)
τ				0.006*	0.014
				(0.003)	(0.009)
θ				-0.340*	-0.362*
				(0.014)	(0.020)
Variance Equation					
δ**(GARCH)**	0.977*	0.890*	0.868*	0.707*	0.800*
	(0.002)	(1.6E-06)	(8.2E-05)	(0.001)	(0.005)
γ**(ARCH)**	-0.043*	-0.048*	-0.059*	0.155*	0.115*
	(0.001)	(0.002)	(0.001)	(0.003)	(0.007)
μ			0.001*	-1.8E-04*	-3.0E-04*
			(8.3E-07)	(5.3E-06)	(2.8E-06)
ν_c					4.0E-07
					(3.1E-07)
ν_g					4.2E-04*
					(1.6E-04)
ν_t					1.3E-04*
					(6.6E-05)
Covariance Equation					
λ	1.053*	0.889*	0.886*	0.645*	0.721*
	(0.002)	(0.006)	(3.9E-05)	(2.5E-04)	(0.010)
ρ	-0.050*	-0.081*	-0.091*	0.047*	0.047*
	(0.001)	(0.002)	(0.004)	(0.017)	(0.002)
ζ_c					6.6E-06*
					(3.7E-07)
ζ_g					9.8E-05
					(1.5E-04)
ζ_t					-8.2E-05
					(7.1E-05)
Log-likelihood	475.4735	475.4735	475.4735	505.9959	505.9959

Note: See the notes associated with Table 2. Countries are selected based on data availability for the relevant variables. Developed non-EU countries are as follows: Australia, Canada, Japan, United States. N= 3, T=1970-2014.

Table 4: Panel GARCH Model for Emerging Countries

	(A)	**(B)**	**(C)**	**(D)**	**(E)**
Mean Equation					
β	0.026*	0.026*	0.026*	0.022*	0.024*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
α	0.417*	0.409*	0.415*	0.388*	0.382*
	(0.010)	(0.008)	(0.008)	(0.013)	(0.037)
κ		-0.002	-0.006	-0.001	0.036
		(0.018)	(0.019)	(0.025)	(0.064)
η				0.002*	0.002*
				(2.3E-04)	(4.9E-04)
τ				-0.041*	-0.050*
				(0.005)	(0.006)
θ				-0.023*	-0.025*
				(0.006)	(0.010)
Variance Equation					
δ**(GARCH)**	0.815*	0.813*	0.792*	0.805*	0.799*
	(0.001)	(0.001)	(3.4E-04)	(0.003)	(0.001)
γ**(ARCH)**	0.062*	0.064*	0.083*	0.048*	0.104*
	(0.004)	(0.005)	(0.005)	(0.005)	(0.006)
μ			4.4E-04*	4.4E-04*	4.5E-04*
			(4.2E-05)	(5.0E-05)	(1.3E-04)
ν_c					5.5E-06*
					(1.5E-06)
ν_g					-2.9E-04
					(2.3E-04)
ν_t					9.8E-05
					(8.8E-05)
Covariance Equation					
λ	0.901*	0.905*	0.918*	0.897*	0.790*
	(0.001)	(5.5E-05)	(0.001)	(0.001)	(0.002)
ρ	-0.041*	-0.043*	-0.046*	-0.029*	0.071*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.009)
ζ_c					3.0E-06*
					(1.4E-06)
ζ_g					2.1E-04
					(2.0E-04)
ζ_t					-7.4E-05
					(7.1E-05)
Log-likelihood	1272.0933	1272.0933	1272.0933	1282.8330	1282.8330

Note: See the notes associated with Table 2. Emerging market countries are determined from the pool of JP Morgan EMBI+, referred by UNCTAD[a] , MSCI Emerging Markets Index[b] and Columbia University's Emerging Market Global Players (EMGP)[c]. Countries available in all three classification are selected if data are available for the relevant variables. Emerging markets used are as follows: Argentina, Brazil, Chile, China, Colombia, Egypt, India, Indonesia, South Korea, Mexico, Peru, Philippines, South Africa, Turkey. N= 14, T=1970-2014.

[a]http://unctadstat.unctad.org/EN/Classifications/UnctadStat.EconomicGroupings.Criterias_EN.pdf
[b]https://www.msci.com/acwi
[c]http://ccsi.columbia.edu/publications/emgp/

Table 5: Panel GARCH Model for Developing Countries: SubSaharan

	(A)	**(B)**	**(C)**	**(D)**	**(E)**
Mean Equation					
β	0.023*	0.020*	0.018*	0.031*	0.047*
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
α	0.419*	0.423*	0.415*	0.390*	0.396*
	(0.030)	(0.028)	(0.027)	(0.027)	(0.051)
κ		0.086*	0.090*	0.170*	0.133*
		(0.024)	(0.030)	(0.025)	(0.047)
η				-0.003*	-0.006*
				(6.3E-05)	(0.001)
τ				-0.010*	0.001
				(0.001)	(0.015)
θ				-0.016*	-0.014
				(0.009)	(0.010)
Variance Equation					
δ**(GARCH)**	0.770*	0.706*	0.714*	0.690*	0.757*
	(0.001)	(0.006)	(0.004)	(0.012)	(4.7E-05)
γ**(ARCH)**	0.122*	0.231*	0.148*	0.185*	0.098*
	(0.013)	(0.017)	(0.016)	(0.022)	(0.009)
μ			0.002*	0.002*	0.002*
			(5.5E-05)	(3.9E-04)	(3.4E-04)
ν_c					-2.0E-05*
					(1.3E-06)
ν_g					3.9E-04
					(2.8E-04)
ν_t					1.9E-03*
					(4.7E-04)
Covariance Equation					
λ	0.593*	0.773*	0.618*	0.607*	0.754*
	(0.017)	(0.010)	(0.006)	(0.077)	(0.003)
ρ	-0.045*	-0.071*	-0.047*	-0.046*	-4.8E-04
	(0.021)	(0.022)	(0.017)	(0.024)	(0.014)
ζ_c					-2.0E-06
					(2.9E-06)
ζ_g					2.2E-04
					(2.4E-04)
ζ_t					-8.6E-05
					(4.0E-04)
Log-Likelihood	554.7498	554.7498	554.7498	560.1912	560.1912

Note: See the notes associated with Table 2. World Bank regional classification is used. Countries used are Botswana, Cote d'Ivoire, Cameroon, Congo, Rep., Gabon, Ghana, Kenya and Lesotho. N= 8, T=1970-2014.

Table 6: Panel GARCH Model for Developing Countries: South Asia

	(A)	(B)	(C)	(D)	(E)
Mean Equation					
β	0.039*	0.033*	0.029*	0.033*	0.044*
	(0.005)	(0.008)	(0.010)	(0.010)	(0.002)
α	0.198*	0.230*	0.276*	0.298*	0.209*
	(0.113)	(0.111)	(0.121)	(0.109)	(0.029)
κ		0.152	0.241	0.148	0.101*
		(0.175)	(0.217)	(0.157)	(0.057)
η				-0.001	-0.002*
				(0.002)	(3.8E-04)
τ				0.038*	0.037*
				(0.011)	(0.007)
θ				-0.020	-0.018
				(0.018)	(0.014)
Variance Equation					
δ**(GARCH)**	0.572*	0.619*	0.642*	0.607*	0.637*
	(0.115)	(0.119)	(0.125)	(0.121)	(0.012)
γ**(ARCH)**	0.210*	0.178*	0.164*	0.212*	0.155*
	(0.110)	(0.100)	(0.100)	(0.130)	(0.001)
μ			-3.3E-04	4.2E-05	6.5E-05*
			(3.2E-04)	(2.1E-04)	(3.6E-05)
ν_c					1.0E-05*
					(8.8E-07)
ν_g					5.4E-05*
					(2.0E-05)
ν_t					-3.2E-05*
					(2.8E-06)
Covariance Equation					
λ	0.516*	0.535*	0.551*	0.556*	0.596*
	(0.158)	(0.168)	(0.178)	(0.195)	(0.042)
ρ	0.150	0.124	0.102	0.126	0.080*
	(0.102)	(0.093)	(0.099)	(0.115)	(0.033)
ζ_c					-3.4E-06*
					(9.9E-07)
ζ_g					2.3E-04*
					(5.2E-05)
ζ_t					-1.5E-04*
					(8.1E-05)
Log-Likelihood	302.1899	302.1899	302.1899	303.5851	303.5851

Note: See the notes associated with Table 2. World Bank regional classification is used. Countries used Bangladesh, Pakistan and Sri Lanka. N= 3, T=1970-2014.

Table 7: Panel GARCH Model for Developing Countries: MENA

	(A)	(B)	(C)	(D)	(E)
Mean Equation					
β	0.032*	0.037*	0.036*	0.037*	0.029*
	(0.002)	(0.001)	(0.002)	(3.9E-04)	(0.003)
α	0.165*	0.166*	0.177*	0.233*	0.250*
	(0.030)	(0.025)	(0.033)	(0.016)	(0.058)
κ		-0.098*	-0.095*	-0.120*	-0.123
		(0.026)	(0.036)	(0.008)	(0.076)
η				0.002*	0.002*
				(3.8E-05)	(0.001)
τ				-0.023*	0.009
				(0.002)	(0.018)
θ				-0.063*	-0.121*
				(0.017)	(0.019)
Variance Equation					
δ**(GARCH)**	0.749*	0.748*	0.750*	0.781*	0.808*
	(0.010)	(0.012)	(0.009)	(0.006)	(0.005)
γ**(ARCH)**	0.118*	0.138*	0.137*	0.061*	0.103*
	(0.015)	(0.014)	(0.014)	(0.005)	(0.003)
μ			-3.0E-05	-5.2E-05	8.3E-05
			(1.7E-04)	(1.4E-04)	(1.9E-04)
ν_c					4.1E-06
					(3.2E-06)
ν_g					-4.6E-04*
					(2.0E-04)
ν_t					-7.6E-05
					(1.5E-04)
Covariance Equation					
λ	0.850*	0.842*	0.869*	0.967*	0.754*
	(0.002)	(0.007)	(0.004)	(0.008)	(0.01)3
ρ	-0.025*	-0.020	-0.032*	-0.057*	0.091*
	(0.013)	(0.013)	(0.011)	(0.001)	(0.003)
ζ_c					2.8E-07
					(2.6E-07)
ζ_g					-2.5E-03*
					(2.4E-04)
ζ_t					2.5E-04*
					(8.5E-05)
Log-Likelihood	517.3412	517.3412	517.3412	518.3583	518.3583

Note: See the notes associated with Table 2. World Bank regional classification is used. Countries used are Algeria, Iran, Israel, Morocco, Oman, Saudi Arabia and Tunisia. N= 7, T=1970-2014.

Table 8: Panel GARCH Model for Developing Countries: Latin America and Caribbean

	(A)	**(B)**	**(C)**	**(D)**	**(E)**
Mean Equation					
β	0.014*	0.014*	0.016*	0.022*	0.026*
	(2.4E-04)	(0.001)	(0.001)	(1.9E-04)	(0.002)
α	0.449*	0.463*	0.458*	0.433*	0.470*
	(0.007)	(0.019)	(0.020)	(0.006)	(0.045)
κ		-0.007	-0.027	-0.030*	-0.106*
		(0.029)	(0.029)	(0.009)	(0.055)
η				-0.002*	-0.002*
				(5.1E-05)	(3.8E-04)
τ				0.001	-0.004
				(0.003)	(0.007)
θ				0.006	0.005
				(0.005)	(0.008)
Variance Equation					
δ**(GARCH)**	0.779*	0.764*	0.785*	0.767*	0.803*
	(0.001)	(0.002)	(0.005)	(1.5E-04)	(3.8E-04)
γ**(ARCH)**	0.090*	0.097*	0.061*	0.079*	0.105*
	(0.002)	(0.007)	(0.009)	(0.001)	(0.003)
μ			3.0E-05*	3.2E-05*	1.3E-04
			(5.6E-06)	(1.0E-05)	(9.4E-05)
ν_c					2.1E-06*
					(6.2E-07)
ν_g					-1.6E-05
					(3.9E-05)
ν_t					-1.2E-04*
					(7.2E-05)
Covariance Equation					
λ	0.891*	0.879*	0.878*	0.878*	0.764*
	(4.1E-04)	(0.003)	(0.003)	(4.1E-05)	(0.006)
ρ	-0.039*	-0.030*	-0.034*	-0.039*	0.084*
	(0.002)	(0.004)	(0.004)	(0.001)	(0.003)
ζ_c					5.6E-06*
					(8.5E-07)
ζ_g					2.2E-05
					(4.3E-05)
ζ_t					-1.8E-04*
					(7.9E-05)
Log-Likelihood	1203.2889	1203.2889	1203.2889	1207.1637	1207.1637

Note: See the notes associated with Table 2. World Bank regional classification is used. Countries used are Bolivia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Nicaragua, Trinidad and Tobago, Uruguay and Venezuela. N= 13, T=1970-2014.

Table 9: Panel GARCH Model for Developing Countries: East Asia

	(A)	**(B)**	**(C)**	**(D)**	**(E)**
Mean Equation					
β	0.031*	0.045*	0.045*	0.076*	0.069*
	(0.004)	(0.003)	(0.001)	(0.005)	(0.003)
α	0.350*	0.393*	0.378*	0.251*	0.297*
	(0.045)	(0.005)	(0.018)	(0.038)	(0.027)
κ		-0.429*	-0.495*	-1.019*	-0.947*
		(0.083)	(0.010)	(0.126)	(0.085)
η				0.001*	0.002*
				(3.7E-04)	(0.001)
τ				-0.092*	-0.036*
				(0.022)	(0.017)
θ				-0.069*	-0.086*
				(0.025)	(0.010)
Variance Equation					
δ**(GARCH)**	0.807*	0.823*	0.790*	0.851*	0.662*
	(0.004)	(1.9E-04)	(3.9E-05)	(0.013)	(1.8E-04)
γ**(ARCH)**	0.037*	0.039*	0.061*	-0.078*	0.098*
	(0.003)	(0.002)	(3.8E-04)	(0.009)	(4.4E-05)
μ			2.9E-04*	-3.2E-04	-3.2E-04*
			(8.4E-06)	(3.6E-04)	(3.5E-05)
ν_c					4.2E-05*
					(9.2E-07)
ν_g					0.001*
					(2.9E-04)
ν_t					0.001*
					(7.2E-05)
Covariance Equation					
λ	0.860*	0.844*	0.826*	1.001*	0.755*
	(0.005)	(2.4E-04)	(1.9E-05)	(0.005)	(0.001)
ρ	0.065*	0.069*	0.085*	-0.079*	0.100*
	(0.002)	(2.7E-05)	(3.5E-04)	(0.005)	(4.7E-04)
ζ_c					1.1E-05*
					(3.2E-07)
ζ_g					7.8E-05
					(2.6E-04)
ζ_t					1.2E-05
					(3.6E-05)
Log-Likelihood	348.8506	348.8506	348.8506	354.3509	354.3509

Note: See the notes associated with Table 2. World Bank regional classification is used. Countries used are Fiji, Malaysia, Singapore and Thailand. N= 4, T=1970-2014.

Table 10: Panel GARCH Model for Least Developed Countries

	(A)	**(B)**	**(C)**	**(D)**	**(E)**
Mean Equation					
β	0.030*	0.031*	0.032*	0.061*	0.062*
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
α	0.091*	0.078*	0.084*	0.063*	0.070*
	(0.024)	(0.019)	(0.024)	(0.022)	(0.023)
κ		**-0.014**	**-0.019**	**0.026**	**0.010**
		(0.030)	**(0.035)**	**(0.033)**	**(0.032)**
η				-0.006*	-0.007*
				(2.8E-04)	(3.1E-04)
τ				0.007	0.014*
				(0.005)	(0.007)
θ				-0.026*	-0.020*
				(0.005)	(0.006)
Variance Equation					
δ**(GARCH)**	0.878*	0.851*	0.843*	0.875*	0.809*
	(2.6E-04)	(0.001)	(1.0E-04)	(2.2E-06)	(1.6E-04)
γ**(ARCH)**	-3.6E-04	0.011*	0.024*	-0.013*	0.019*
	(0.004)	(0.003)	(0.005)	(0.002)	(0.006)
μ			**4.2E-04**	**0.001***	**3.9E-04**
			(2.9E-04)	**(1.5E-04)**	**(3.5E-04)**
ν_c					7.7E-06*
					(2.1E-06)
ν_g					3.8E-04
					(2.6E-04)
ν_t					-1.1E-04
					(2.9E-04)
Covariance Equation					
λ	0.922*	0.894*	0.874*	0.905*	0.872*
	(0.003)	(0.006)	(8.3E-07)	(0.001)	(0.001)
ρ	-0.041*	-0.042*	-0.045*	-0.042*	-0.025*
	(0.003)	(0.004)	(0.005)	(0.002)	(0.003)
ζ_c					1.2E-06*
					(7.2E-07)
ζ_g					-2.9E-04*
					(4.8E-05)
ζ_t					-8.1E-05
					(6.3E-05)
Log-Likelihood	1055.6054	1055.6054	1055.6054	1066.4099	1066.4099

Note: See the notes associated with Table 2. World Bank income level classification is used. Countries used are Benin, Burkina Faso, Burundi, Central African Republic, Chad, Madagascar, Malawi, Mali, Mauritania, Niger, Rwanda, Senegal, Sierra Leone, Sudan and Togo. N= 15, T=1970-2014.

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