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# Output Volatility in Latin America: Evidence from a Multivariate GARCH Model

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**Abstract** Following the 2008 financial crisis, interest has increased in different types of international "contagion"— spillovers among countries that occur for a number of economic and non-economic reasons. In this study, we focus on real contagion in Latin America over the period from 1998 to 2012. We find that only Mexico and Brazil, and not Chile or Peru (or the United States), show evidence of time-varying output volatility. Multivariate GARCH methods allow us to test for spillovers among these countries and a set of foreign proxies. We conclude that both Brazil and Mexico experience spillovers that originate in the IMF's Advanced Economies industrial production index, while Brazil is tied to the European Union. Volatility in both Latin American nations is also linked to movements in regional commodity prices.

*Keywords*: Volatility, Output, Latin America, GARCH

*JEL Classification*: F41

## 1. Introduction

In recent decades—particularly following the 1997 Asian Crisis and the 2008 Global Financial Crisis—economic turmoil has spread worldwide, beyond national borders, to countries that are linked by trade and investment channels. Sometimes—as was the case in 1998, when Brazil experienced "contagion" from Asia—the underlying economic connections are unpredictable. But, for as much attention as financial transmission (such as in exchange rates or interest rates) commands, real contagion—in aggregates such as output—is just as important.

Real transmission can work directly through trade channels—a drop in income reduces a country's imports, and therefore its partner's exports. But it also often works indirectly through financial channels. Exchange-rate depreciation in one nation, brought on by an output decline, can result in an appreciation of its neighbor's bilateral rate. As a result, the trading partner's exports, and thus output, must decline as well. Likewise, a financial crisis can result in one country's "credit crunch," which might have an impact on lending—and thus output—in the region. This can be exacerbated by capital flows, particularly when volatile "hot money" is withdrawn by international investors. The net result is that one nation's output volatility might have an impact on another's, and this might originate either within a region or from large economies outside it.

This study examines Latin America over the past decade and a half, beginning in 1998. We use monthly series of Industrial Production to proxy output for Brazil, Mexico, Chile, and Peru, as well as for three external actors (the U.S., the European Union, and the International Monetary Fund's Advanced Economies index). Using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) methods, we analyze these series' volatility properties. Since the two smaller Latin American countries do not exhibit time-varying volatility, we focus on Mexico and Brazil. After modeling the resulting volatility series based on univariate methods, we apply Multivariate GARCH to test for spillovers.

## 2. Relationship to the Literature

Most studies of macroeconomic volatility focus either on its relationship with economic growth or on volatility's determinants. This is often performed for large panels of countries. Ramey and Ramey (1995), for example, find that macroeconomic volatility leads to lower output growth in 92 nations; Imbs (2007) arrives at similar results. In the second strand of the literature, Karras and Song (1996) examine the contribution of such factors as economic openness, exchange-rate flexibility, fiscal policy, and shocks to the money supply and technology. Karras (2006) continues this research with an examination of the role of economic openness and country size. The impact of economic (particularly financial) integration is particularly scrutinized, since economic theory suggests that greater opportunities for risk-sharing and consumption-smoothing can reduce such fluctuations. The converse might happen, however, if integration opens more channels for financial contagion to spread. Kose *et al.* (2003) perform an important empirical study, finding a "U-shaped" pattern whereby some countries receive net benefits and others are exposed to higher risk. Theories behind such effects have been developed by Buch *et al.* (2005), Evans and Hnatkovska (2007), and Özbilgin (2009).

Other analyses focus on terms of trade shocks for particular regions as well as globally. Hirata *et al.* (2007) do so for the case of the Middle East and North Africa, while Kim (2007) examines a large group of nations worldwide. But few countries look at direct spillovers of output volatility for specific regions. Bayoumi and Swiston (2009) apply Vector Autoregressive (VAR) methods to a series of developed-country GDP growth rates and the rest of the world, but do not look at volatility *per se*. Hegerty (2012) examines transition economies, using both VAR and GARCH approaches, and concludes that transmission is more likely among the relatively advanced Visegrad countries such as the Czech Republic and Poland than for later EU entrants such as Romania.

This study looks for evidence of volatility transmissions in Latin America, rather than the underlying causes, using the GARCH approach of Engle (1982) and Bollerslev (1986). Examining deseasonalized monthly industrial production data, we find that Brazilian volatility is more closely tied to economies outside the region than is Mexican variability. This paper proceeds as follows. The methodology is outlined in Section II. Section III explains the results, and Section IV concludes.

## 3. Methodology

For our output measures, we use monthly indices of industrial production, which we deseasonalize using the Census X-12 procedure. Data are taken from the International Financial Statistics (IFS) of the IMF. These series are for Brazil, Mexico, Chile, and Peru, as well as for the United States, the European Union, and the IMF's "Advanced Economies" index. The data span 1998m1 to 2012m10.

Figure 1 shows these series both in (log) levels and in log changes. We see volatility during the recent period of turmoil, but also following the 1997-1998 Asian Crisis. Perhaps surprisingly, Brazil does not register an abnormally large drop during its crisis and devaluation of 1998 and 1999.

Each series is measured as log changes (month-on-month growth rates), and modeled as an ARMA($p$,$q$) process following the standard Box-Jenkins methodology:

$$\Delta y_t = c + \sum_{i=1}^{p} \rho_i \Delta y_{t-1} + \sum_{j=0}^{q} \theta_j \varepsilon_{t-j} \quad \text{(1a).}$$

Each of these equations is tested for ARCH errors, and if time-varying volatility exists, each error term is modeled as a GARCH(1,1) process. In some cases, additional tests point to a GARCH(1,2) model.

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_3 h_{t-1} \quad \text{(1b).}$$

$$h_t = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 \varepsilon_{t-2}^2 + \beta_3 h_{t-1} \quad \text{(1c).}$$

The resulting variance series is generated as a measure of output volatility for the relevant countries.

As a preliminary test, these GARCH variance series are entered into a matrix that contains Latin American volatility as well as a foreign proxy. Granger causality (Block exogeneity) tests allow us to see where one country's fluctuations might lead to variance elsewhere. This well-known procedure tests for the significance of an additional variable in a regression; increased explanatory power indicates Granger causality. We expect there to be linkages that originate both within Latin America and outside the region.

In our main multivariate analysis, we then estimate a multivariate GARCH model in which each appropriate industrial production series is modeled as an AR(1) process as in Equation (2a), with the ARCH and GARCH estimates estimated in Equation (2b) and constant conditional correlations shown in Equation (2c):

$$\Delta y_{i,t} = c + \rho_i \Delta y_{i,t-1} + \varepsilon_t \qquad \text{for all i} \quad \text{(2a);}$$

$$\ln \sigma_{i,t}^2 = \alpha_{i,0} + \sum_{j}^{8} \left( \alpha_{i,j} \phi_i \varepsilon_{i,t-1}^2 + \beta_{i,j} \ln \sigma_{j,t-1}^2 \right) \quad \text{for all i, j} \quad \text{(2b);}$$

$$\sigma_{i,j,t} = \gamma_{i,j} \sigma_{i,t} \sigma_{j,t} \qquad \text{for all i, j; i} \neq \text{j} \quad \text{(2c).}$$

These models are similar to those used by Laopodis (2000, 2001, 2002) or Hegerty (2011) in studies of interest-rate volatility, or by Hegerty (2012) for output volatility. We then use these results to examine international output spillovers in the specific case of Latin America.

As an additional test, we also include Latin American inflation rates and exchange-rate movements in a larger system, to see whether either type of volatility spills over to output. These data, also taken from the IFS, include log changes in CPI and in domestic currency units per U.S. dollar. In addition, we follow Hegerty (2014) and create a commodity price index that is the first principal component of log changes in the IFS' Oil, Coffee and Copper Price indexes. While not a proxy for GDP, it does test for the potential impact of commodity-price fluctuations on this output volatility. Our results find evidence of all types of volatility transmission, as is explained below.

## 4. Results

Table 1 provides a number of test statistics. First, the Phillips-Perron (1988) test, which is similar to the Augmented Dickey-Fuller test except for the fact that it uses Newey-West (1983) standard errors instead of lags to control for autocorrelation, shows that all series are stationary. More important, our ARCH test—first estimated at 12 lags and then re-estimated at the highest lag for which there was a significant coefficient—show that neither Chile, Peru, nor the U.S. show evidence of time-varying volatility. We therefore continue our analysis for Brazil and Mexico, using the Advanced Economies (AE) and the EU as our foreign output proxies.

Table 2 gives our single-equation GARCH estimates. It is important to note that additional testing (not shown here) showed no evidence of GARCH-in-Mean effects that might be expected if output volatility hinders growth. We therefore estimate "simple" GARCH(1,1) or GARCH(2,1) models, as in Equations (1b) and (1c), for all countries.

These models are well-specified and have significant coefficients throughout. The resulting GARCH variance series are provided in Figure 2. As expected, there is a volatility increase around the 2008 financial crisis; Mexico's series exhibits high variance afterward as well.

These volatility series are next entered into two separate vectors, one for each foreign output proxy. Minimizing the Schwarz Criterion, they are estimated at three lags for the VAR that includes the AE index, and two lags for the EU vector. We find in Table 3 that Brazilian output volatility Granger-causes Mexican volatility, but not necessarily vice-versa; the corresponding p-value is too high in the AE specification. Most importantly, Brazilian volatility Granger-causes fluctuations in the rest of the world, but Mexico does not. This implies that Brazil might have more of a "global" influence.

Most results are confirmed by the Multivariate GARCH results that are given in Table 4.
The ARCH and GARCH coefficients show that EU volatility has a negative effect on Brazilian variance, while the AE index has a positive impact on Mexico. The Advanced Economies are more affected than is the EU. The conditional correlations show a linkage between the EU and Brazil, and the AE index and both Latin American nations, but no connection between Brazil and Mexico.

Table 5 shows the conditional correlations for the expanded model that includes Brazilian and Mexican exchange rates and inflation rates. Three specifications are estimated, using the AE index and EU industrial production, as well as our index of important commodity prices. We see that AE growth variability is correlated with that of both Latin American countries, while EU industrial production is tied only to that of Brazil. Regarding the other variables, Brazilian and Mexican exchange-rate movements are positively correlated with one another. At the same time, Brazilian growth volatility is negatively correlated with a rising Mexican peso, while Mexican inflation and exchange-rate appreciation are positively correlated. Examining the role of commodity prices, we find a positive relationship between our index and growth for both Brazil and Mexico. We can therefore conclude that commodity price movements have a direct impact on these large Latin American economies.

## 5. Conclusion

The recent financial crisis has led to increased interest in international "contagion," primarily with regard to exchange rates and capital flows. While the 1997 Asian Crisis has been studied in depth, the 2008 financial crisis is just beginning to be examined using time-series econometric methods. Further, many analyses focus on financial variables rather than real ones. This study looks at output volatility in a set of

Latin American countries, using monthly data from 1998 to 2012, testing for volatility spillovers both within the region and originating outside it.

Multivariate GARCH methods, supplemented by univariate tests, arrive at the following conclusions. First, not every country exhibits the time-varying volatility that makes it suitable for GARCH analysis. Of our sample, we exclude Chile, Peru, and the United States and focus on Brazil, Mexico, the European Union and the IMF's "Advanced Economies" industrial production index. Secondly, while Granger causality tests suggest that there are considerable spillovers between Brazil and Mexico, this is not borne out by multivariate GARCH. In fact, Brazil has stronger ties to the European Union. Mexico's strongest links are with the Advanced Economies, most likely due to the United States' prominence in this index. These results suggest that Brazil is living up to its status as a major emerging market, while Mexico plays more of a regional role. Finally, an expanded model suggests that commodity-price volatility increases output fluctuations.

## Endnotes

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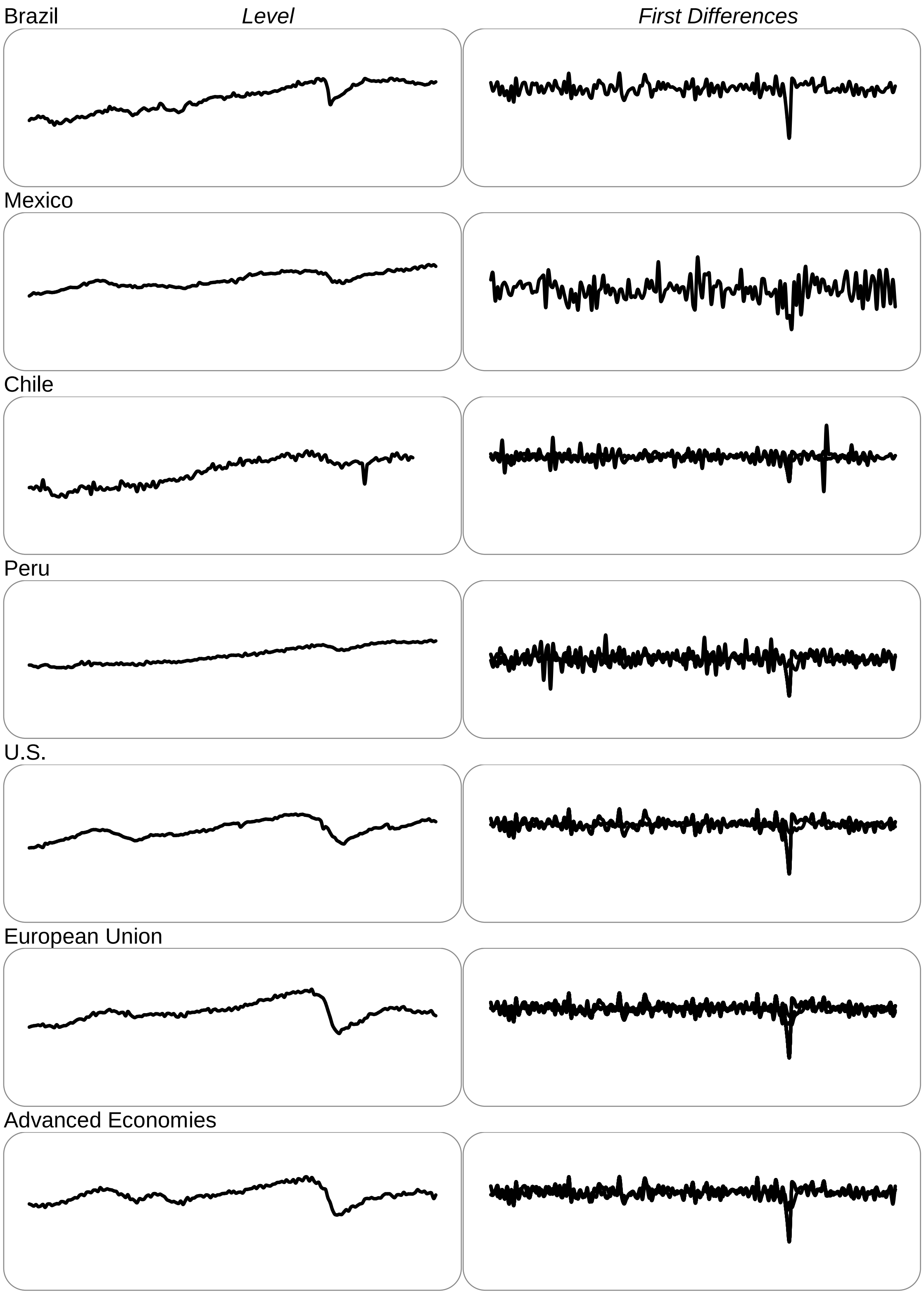
**Figure 1. Latin American and Partner Industrial Production Indices (and Log Changes)**



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## Table 1. Phillips-Perron and ARCH Test Results

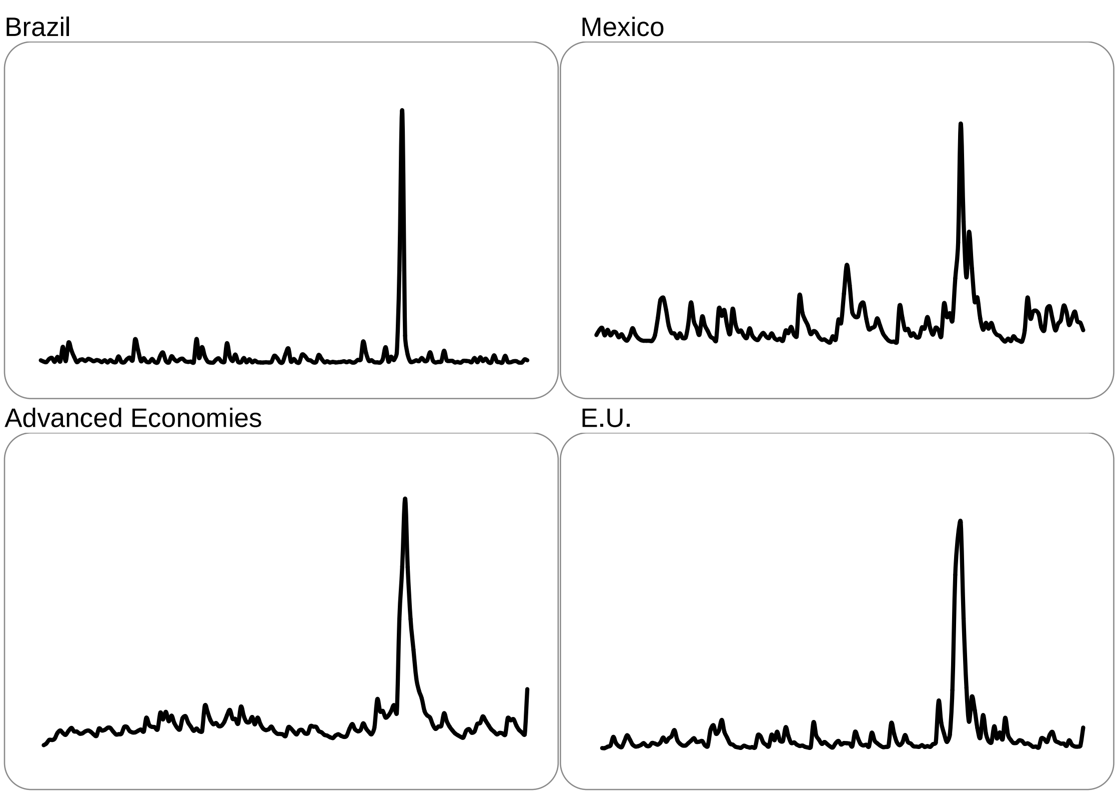
| | PP (p-value) | ARMA(p,q) | ARCH | Order |
|---|---|---|---|---|
| Brazil | -12.521 (0.000) | (1,0) | 11.438 (0.001) | 1 |
| Mexico | -14.940 (0.000) | (1,3) | 22.040 (0.009) | 9 |
| Chile | -27.095 (0.000) | (2,0) | 3.603 (0.730) | 6 |
| Peru | -21.025 (0.000) | (2,1) | 12.354 (0.338) | 11 |
| US | -12.470 (0.000) | (2,2) | 6.687 (0.878) | 12 |
| EU | -12.837 (0.000) | (3,0) | 41.715 (0.000) | 11 |
| AE | -14.604 (0.000) | (2,3) | 35.390 (0.000) | 6 |
| PC | -8.978) (0.000) | (2,0) | 14.006 (0.016) | 5 |

## Table 2. Single-Equation GARCH Estimates

| | Brazil | Mexico | Advanced Economies | EU |
|---|---|---|---|---|
| C | **0.003 (0.000)** | **0.002 (0.047)** | **0.001 (0.019)** | **0.001 (0.086)** |
| AR(1) | **0.101 (0.032)** | **0.425 (0.022)** | **-1.028 (0.000)** | **-0.304 (0.000)** |
| AR(2) | | **-0.640 (0.000)** | **-0.727 (0.000)** | 0.067 (0.367) |
| AR(3) | | | | **0.321 (0.000)** |
| MA(1) | | 0.146 (0.149) | **0.882 (0.000)** | |
| MA(2) | | **0.237 (0.005)** | **0.744 (0.000)** | |
| MA(3) | | | **0.347 (0.000)** | |
| Variance Equation | | | | |
| C | **0.000 (0.000)** | 0.000 (0.156) | **0.000 (0.069)** | 0.000 (0.107) |
| RESID(-1)^2 | **0.349 (0.080)** | **0.206 (0.093)** | **0.188 (0.069)** | 0.271 (0.109) |
| RESID(-2)^2 | **-0.202 (0.057)** | | **-0.246 (0.014)** | |
| GARCH(-1) | **0.492 (0.000)** | **0.542 (0.023)** | **1.049 (0.000)** | **0.437 (0.093)** |
| Q(12) | 13.018 (0.292) | 9.352 (0.313) | 19.202 (0.008) | 13.646 (0.135) |
| TR2 | 2.491 (0.115) | 0.026 (0.872) | 1.362 (0.243) | 1.287 (0.257) |
| AIC | -5.363 | -6.436 | -6.546 | -6.498 |

Bold = significant at 10 percent.

## Figure 2. GARCH Variance Series, 1998-2010



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## Table 3. Granger Causality/Block Exogeneity Results, GARCH Variance Series

| Caused by ↓ | Volatility in → Brazil | Mexico | AE |
|---|---|---|---|
| Brazil | | **167.518 (0.000)** | **71.047 (0.000)** |
| Mexico | 5.722 (0.126) | | 5.457 (0.141) |
| AE | **90.760 (0.000)** | **12.575 (0.006)** | |
| All | **106.720 (0.000)** | **232.486 (0.000)** | **127.509 (0.000))** |
| | Brazil | Mexico | EU |
| Brazil | | **108.528 (0.000)** | **35.518 (0.000)** |
| Mexico | **9.687 (0.008)** | | 2.447 (0.294) |
| EU | **177.825 (0.000)** | **6.367 (0.041)** | |
| All | **196.060 (0.000)** | **187.681 (0.000)** | **36.839 (0.000)** |

Bold = significant at 10 percent.

## Table 4. Multivariate GARCH Results

| | | *EU Specification* | | | *Advanced Economies Specification* | | |
|---|---|---|---|---|---|---|---|
| | | Brazil | Mexico | EU | Brazil | Mexico | AE |
| C | | **0.003 (0.005)** | **0.002 (0.002)** | **0.001 (0.001)** | **0.003 (0.003)** | **0.002 (0.002)** | **0.001 (0.017)** |
| AR | | -0.066 (0.336) | **-0.170 (0.025)** | **-0.294 (0.000)** | -0.060 (0.424) | **-0.173 (0.020)** | **-0.341 (0.000)** |
| C | BR | **0.000 (0.000)** | 0.000 (0.609) | **0.000 (0.000)** | **0.000 (0.000)** | 0.000 (0.835) | **0.000 (0.013)** |
| | MX | 0.000 (0.672) | 0.000 (0.153) | 0.000 (0.293) | 0.000 (0.786) | 0.000 (0.105) | 0.000 (0.128) |
| | EU/AE | **0.000 (0.001)** | 0.000 (0.590) | **0.000 (0.000)** | **0.000 (0.013)** | 0.000 (0.105) | **0.000 (0.001)** |
| ARCH | BR | 0.327 (0.108) | 0.030 (0.816) | **0.143 (0.003)** | 0.315 (0.129) | 0.090 (0.153) | **0.124 (0.075)** |
| | MX | 0.027 (0.866) | 0.149 (0.118) | **0.181 (0.025)** | 0.020 (0.894) | 0.182 (0.045) | 0.092 (0.113) |
| | EU | 0.185 (0.005) | 0.103 (0.294) | **0.393 (0.000)** | 0.119 (0.075) | 0.097 (0.115) | **0.134 (0.061)** |
| GARCH | BR | 0.009 (0.680) | -0.202 (0.911) | -0.017 (0.536) | -0.023 (0.487) | 0.038 (0.793) | **0.669 (0.000)** |
| | MX | -0.041 (0.979) | **0.636 (0.001)** | 0.319 (0.176) | -0.001 (0.999) | **0.584 (0.001)** | **0.729 (0.000)** |
| | EU/AE | **-0.425 (0.009)** | 0.429 (0.348) | **-0.248 (0.001)** | -0.420 (0.190) | **0.717 (0.000)** | **0.660 (0.000)** |
| AIC | -18.315 | | | | -18.098 | | |
| Conditional Correlations | | | | | | | |
| | | BR | MX | EU | | MX | AE |
| | BR | | 0.087 (0.336) | **0.344 (0.000)** | BR | 0.091 (0.324) | **0.330 (0.000)** |
| | MX | | | 0.075 (0.339) | MX | | **0.216 (0.009)** |

Bold = significant at 10 percent.

## Table 5. Multivariate GARCH Conditional Correlations, Extended Model

| | BR_EX | BR_INF | MX_IP | MX_EX | MX_INF | AE_IP |
|---|---|---|---|---|---|---|
| BR_IP | -0.030 (0.722) | 0.041 (0.555) | 0.091 (0.314) | **-0.157 (0.019)** | -0.106 (0.149) | **0.324 (0.000)** |
| BR_EX | | -0.012 (0.889) | -0.023 (0.731) | **0.459 (0.000)** | 0.028 (0.690) | -0.052 (0.442) |
| BR_INF | | | -0.048 (0.397) | -0.100 (0.169) | -0.056 (0.473) | -0.068 (0.327) |
| MX_IP | | | | -0.023 (0.747) | -0.007 (0.923) | **0.224 (0.006)** |
| MX_EX | | | | | **0.139 (0.049)** | -0.097 (0.203) |
| MX_INF | | | | | | -0.025 (0.748) |

AIC= -7.148

| | BR_EX | BR_INF | MX_IP | MX_EX | MX_INF | EU_IP |
|---|---|---|---|---|---|---|
| BR_IP | -0.031 (0.714) | 0.042 (0.551) | 0.088 (0.325) | **-0.156 (0.019)** | -0.106 (0.152) | **0.343 (0.000)** |
| BR_EX | | -0.010 (0.906) | -0.021 (0.750) | **0.459 (0.000)** | 0.028 (0.688) | -0.038 (0.643) |
| BR_INF | | | -0.047 (0.405) | -0.102 (0.163) | -0.058 (0.458) | -0.036 (0.648) |
| MX_IP | | | | -0.020 (0.780) | -0.011 (0.885) | 0.072 (0.354) |
| MX_EX | | | | | **0.140 (0.046)** | -0.066 (0.459) |
| MX_INF | | | | | | -0.004 (0.961) |

AIC= -7.375

| | BR_EX | BR_INF | MX_IP | MX_EX | MX_INF | PC |
|---|---|---|---|---|---|---|
| BR_IP | -0.030 (0.732) | 0.040 (0.568) | 0.082 (0.354) | **-0.160 (0.018)** | -0.106 (0.156) | **0.234 (0.002)** |
| BR_EX | | -0.008 (0.925) | -0.022 (0.741) | **0.457 (0.000)** | 0.029 (0.680) | **-0.305 (0.000)** |
| BR_INF | | | -0.048 (0.401) | -0.106 (0.149) | -0.053 (0.498) | -0.045 (0.513) |
| MX_IP | | | | -0.014 (0.844) | -0.013 (0.869) | **0.152 (0.039)** |
| MX_EX | | | | | **0.141 (0.044)** | **-0.374 (0.000)** |
| MX_INF | | | | | | -0.025 (0.729) |
| AIC= 2.126 | | | | | | |

Bold = significant at 10 percent.