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## THE EQUITY PREMIUM, FINANCIAL CRISES AND THE BUSINESS CYCLE: EVIDENCE FROM MEXICO

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# Equity Premium, Financial Crises and the Business Cycle: Evidence from Mexico.

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**Abstract**

Using Mexican data, this paper considers the effects of business cycle fluctuations on the stock market. By employing an equity risk premium analysis, it is first shown that the phase of the cycle (i.e. the contraction or expansion phase) has asymmetric implications for the behavior of stock returns. We then show that financial crises also generate significant differences in excess returns depending on the origin of the crisis. We find that the tequila crisis had a greater impact on the equity risk premium, the volatility of excess return and volatility of all macroeconomic factors when compared to the recent 2008 financial crisis. Finally, the paper investigates the effects of negative demand (i.e. output) and supply (i.e. inflation) shocks for the equity risk premium. We find evidence of asymmetric effects which depend not only on the type of shock, but also on the sign of the shock. In particular, positive supply shocks and negative demand shocks are found to be more important and have a more persistent effect on the equity risk premium, inflation and production growth.

# Contents

# 1 Introduction

Over the last 20 years, the value of the Mexican stock exchange market has gone from 7.5% of GDP to 44.6%. Today, the Mexican stock exchange represents 17 different industries, of which the main industries are telecoms, retail and mining. The Mexican stock exchange index (IPC) has increased 2,485% in 20 years but its five largest members represent 56% of the index making it vulnerable to changes in value of a small number of firms. The purpose of this paper is to investigate the relationship between the Mexican stock market returns and fluctuations in the business cycle. Specifically, we want to consider if the impact of business cycle contractions on stock returns varies depending on the source of the macroeconomic shock.

In Mexico there have been four different cycles since 1982, the most important being the business cycle from October 1992 until October 2000. This cycle was characterized by a double dip recession, which is not very common to see. From 1988 until 2013 there have been four recessions. Our analysis be focused on the 1994 recession known as the tequila crisis and the recent 2008 financial crisis. This is because one of the crisis was originated in only by Mexican factors while the recent 2008 financial crisis was originated only by external factors. We will use these differences to see if the impact of the business cycle changes.

In classical asset pricing theory, an asset price depends on the present value of expected asset income and expectations about future income are formed from all available information. Also, when there exists some kind of risk related to future income, the price of the asset has to be lower but the return to compensate the risk has to be higher. This compensation is known as the risk premium. Since prices depend on the present value of future returns, they must depend on the interest rate (discount rate). The interest rate determines the present value of future income or returns. Then, the riskier the asset, the higher the interest rate has to be to compensate for the risk taken. Also, during a recession, firms earnings fall and thus asset prices fall resulting in a negative relation between output and stock prices. All these theoretical relationships between asset prices, returns, risk and macroeconomic variables are going to be used as basis to estimate the relationship between the business cycle and stock returns.

Following the methodology of Smith, Sorensen and Wickens (2010), we employ a multivariate GARCH-in-mean model. The data we use are stock prices for 120 firms listed on the Mexican stock exchange and three macroeconomic factors (inflation, production growth and money growth), to capture the effect of the business cycle on stock returns through the equity risk premium. We find that the three macroeconomic factors are significantly priced by the stock market. It is shown that the two financial crises analyzed induce very different effects on the equity risk premium and its volatility. The most important crisis for stock returns is the tequila crisis during which the equity risk premium touched a historic peak and also went below zero. We also find that the effect of demand shocks differ from the effect of a supply shocks on equity risk premium and that the effect between supply and demand shock is inversed when the sign of the shock changes. The most important and persistent shocks for the Mexican stock market are found to be negative demand shocks and positive supply shocks.

This paper contributes to a literature that focuses on the relationship between macroeconomic factors and different aspects of the stock market. Smith, Sorensen and Wickens (2010) analyze the effect of the U.S. business cycle on U.S. stock market returns through the equity premium. They find that macroeconomic factors have a significant impact on the American stock market through the volatility of returns and that the effect on returns is different if it comes from a demand or a supply shock. Naes, Skjeltorp and Odegaard (2010) analyze the liquidity in the stock market as a precursor of a crisis in the real economy. They find a strong relationship between the stock market liquidity and the business cycle. Hamilton and Gin (1998) investigated the joint series behavior of stock returns and growth of industrial production. They used a bivariate model and found that economic recessions are the primary factor that drives fluctuations in the volatility of stock returns. In related work for an emerging market, Al-Rjoub and Azzam (2012) use the same methodology as Smith, Sorensen and Wickens (2010) and find that economic crises have a negative impact on stock returns and that the effect of the 2008 financial crisis was the most severe, it had the larger drop of stock prices and the higher volatility, for Jordan. For Mexico, Cermeño and Solis (2012) use symmetric and asymmetric GARCH models to analyze the effect of expected and unexpected news about economic performance in Mexico and the U.S. on the Mexican stock market. The find evidence of a link between the dynamics in daily stock excess returns and the arrival of new economic information. Also for Mexico, Treviño (2011) uses iterated non-linear seemingly unrelated regressions to examine the pricing of macroeconomic factors in the Mexican stock market and finds little evidence in favor of a linear relationship specification between macroeconomic factors and excess return.

The methodology we use following Smith, Sorensen and Wickens (2010) has never been used before to analyze the relationship between the business cylcle and the stock market return in Mexico. The results found on this relationship for Mexico are similar to what was found for the U.S., but the difference between the effects of the business cycle on the equity risk premium for the two different crises has not been shown before. These results are important to be able to have a better understanding of the Mexican stock market, both for investors and policy makers. For instance, we found that a negative demand shock has an important and persistent effect en the equity risk premium.

The reminder of the paper is organized as follows. Section 2 presents the theoretical framework of the model beginning with asset pricing. Then we introduce the econometric model and set out the two channels through which the excess return of the Mexican stock market can be affected by the business cycle. In Section 3, we explain the data, then present the estimation results of the model and finally analyze the response of the equity risk premium and the macroeconomic factors to a positive and negative demand

and supply shocks. Finally, Section 5 concludes.

# 2 Theoretical Framework

## 2.1 Asset pricing

In asset pricing theory the expected return of a financial asset can be modeled as a linear function of various macroeconomic factors.[1] Further, the expected return of an asset shows how the market will price that asset in relation to it's risk. The market reward-to-risk is effectively the market risk premium, which is the difference between a risky asset's return and the risk free rate (excess return). For the expected return to increase, keeping the risk free rate constant, an economic agent must take on more risk. The measure of risk used in equity markets is typically the volatility of a security's price over a number of periods. Thus, the expected excess return of an asset is related to the risk factors that create volatility. That is, the price of an asset is equal to the sum of its future returns discounted by stochastic factors (i.e. the risk factors that create volatility).

For that reason the model is going to be based on stochastic discount factors (SDF). Closely following Smith, Sorensen and Wickens (2010), the SDF can be expressed as:[2]

$$P_t = E_t\{M_{t+1}(X_{t+1})\} \tag{1}$$

where $P_t$ is the price of an asset at time t, $M_{t+1}$ is the SDF ($0 \leq M_{t+1} \leq 1$) and $X_{t+1}$ is the payoff of an asset in period $t+1$.[3] The relationship states that the price of an asset is the expectation of its discounted future payoffs using the SDF, given all available information at time t.[4] Equation (1) can be expressed in terms of the nominal rate of return:

[1] See Ross (1976) for further details.
[2] See Ferson (2003) for further details.
[3] The random variable $M_{t+1}$ is also known as the pricing kernel.
[4] See Smith and Wickens (2002) for further detail.

$$1 = E_t\left[M_{t+1}\frac{X_{t+1}}{P_t}\right] = E_t[M_{t+1}(1+I_{t+1})\frac{P_t}{P_{t+1}}] \tag{2}$$

where $I_t$ is the nominal interest rate. Following Cochrane (2005) and Smith and Wickens (2002) and with $m_t = ln(M_t)$, $\pi_{t+1} = ln(P_{t+1}/P_t)$ and $i_t = ln(1+I_t)$:

$$E_t[m_{t+1}(i_{t+1})\frac{1}{\pi_{t+1}}] = 1.$$

In terms of covariance:

$$E_t[i_{t+1}] = \frac{1 - Cov_t[(m_{t+1}/\pi_{t+1}), i_{t+1}]}{E_t[m_{t+1}/\pi_{t+1}]}. \tag{3}$$

If $i_{t+1} = i_t^f$ (the risk free rate), then:

$$E_t[m_{t+1}(i_{t+1})\frac{1}{\pi_{t+1}}] = i_t^f E_t[(m_{t+1}/\pi_{t+1})] = 1$$

and by substituting in (3) we get the no-arbitrage equation:

$$E_t[i_{t+1}] = i_t^f - Cov_t[(m_{t+1}/\pi_{t+1}), i_{t+1}]i_t^f$$

$$E_t[i_{t+1}] - i_t^f = -Cov_t[(m_{t+1}/\pi_{t+1}), i_{t+1}]i_t^f$$

$$E[i_{t+1} - i_t^f] = -Cov_t[(m_{t+1}/\pi_{t+1}), i_{t+1} - i_{t+1}^f]i_t^f. \tag{4}$$

The risk premium is defined as the price of risk times the quantity of risk

$$risk\, premium = -Cov_t[(m_{t+1}/\pi_{t+1}), i_{t+1}]i_t^f = \beta_t\lambda_t$$

$$\beta_t = price\, of\, risk = -i_t^f\frac{Cov_t[(m_{t+1}/\pi_{t+1}), i_{t+1}]}{(V_t(i_{t+1} - i_t^f))^{1/2}}$$

$$\lambda_t = quantity\, of\, risk = (V_t(i_{t+1} - i_t^f))^{1/2}$$

assuming that $i_t$,$m_t$,$i_t^f$ and $\pi_t$ are jointly normally distributed, the no-arbitrage condition, equation (4), under log-normality can be expressed as:[5]

$$lnE_t[\frac{m_{t+1}(i_{t+1} - i_t^f)}{\pi_{t+1}}] = E_t[ln(m_{t+1}) - ln(\pi_{t+1}) + ln(i_{t+1} - i_t^f)] + \frac{1}{2}V_t[\frac{ln(m_{t+1}(i_{t+1} - i_t^f))}{\pi_{t+1}}] = 0$$

$$= E_t(m_{t+1}) - E_t(\pi_{t+1}) + E_t(i_{t+1} - i_t^f) + \frac{1}{2}V_t(m_{t+1}) + \frac{1}{2}V_t(i_{t+1} - i_t^f) + \frac{1}{2}V_t(\pi_{t+1})$$

$$+Cov_t(\pi_{t+1}, i_{t+1} - i_t^f) + Cov_t(m_{t+1}, i_{t+1} - i_t^f) = 0 \qquad (5)$$

If $i_t^f = i_{t+1}$, equation (5) becomes:

$$lnE_t[\frac{m_{t+1}(i_{t+1} - i_t^f)}{\pi_{t+1}}] = E_t(m_{t+1}) - E_t(\pi_{t+1}) + \frac{1}{2}V_t(m_{t+1}) + \frac{1}{2}V_t(\pi_{t+1}) = 0 \qquad (6)$$

substituting (6) in (5) we get:

$$E_t(i_{t+1} - i_t^f) + \frac{1}{2}V_t(i_{t+1}) = -Cov_t(m_{t+1,}i_{t+1}) + Cov_t(\pi_{t+1}.i_{t+1}). \qquad (7)$$

The SDF can be expressed as a linear function of n factors $z_{it}$:

$$m_t = -\sum_{i=1}^{n} \beta_i z_{it}$$

With the former condition we can express equation (7) as:

[5] If $ln\, x$ is $N(\mu, \sigma^2)$then $E(x) = exp(\mu + \sigma^2/2)$ and $ln\, E(x) = \mu + \sigma^2/2$.

$$E_t(i_{t+1} - i_t^f) = -\beta_0 V_t(i_{t+1}) + \sum_{i=1}^{n} \beta_i Cov_t(z_{it}, i_{t+1}). \quad (8)$$

Equation (8) can be expressed as a measure of excess return by unit of risk, the Sharpe ratio:

$$\frac{E_t(i_{t+1} - i_t^f)}{(V_t(i_{t+1}))^{1/2}} = -\frac{1}{2}(V_t(i_{t+1}))^{1/2} + \sum_{i=1}^{n} \beta_i (V_t(z_{i,t+1}))^{1/2} Corr_t(z_{i,t+1}, i_{t+1})$$

Since it is almost impossible to hedge for all business cycle variations, we would expect that these variations reflect too on the stock market. As mentioned in the introduction, there is both theoretical and empirical evidence for the close relationship between the stock market price and variation in macroeconomic variables. For that reason the discount factors used in the model will be macroeconomic variables in order to measure the impact of the business cycle on the Mexican stock market.

## 2.2 Econometric model

Following the methodology of Smith, Sorensen and Wickens (2010), we analyze the Mexican business cycle effects on the Mexican stock market within a no-arbitrage framework using a generalized SDF model with three macroeconomic factors (inflation, money growth and industrial production growth). This methodology will create two channels of transmission, one is through the mean of excess returns of the market and the other through the conditional volatility of excess returns.

As in Smith, Sorensen and Wickens (2010), a multivariate GARCH-in-mean model will be estimated to allow the excess return to depend on its own conditional variance. Thus, the equity risk premium will be an increasing function of the conditional variance of the excess return. Multivariate GARCH models also have the advantage that the contemporaneous shocks to variables can be correlated with each other. Moreover, multivariate GARCH models allow for volatility spillovers.[6]

[6] See Enders for further details.

In order to estimate the conditional variance, a BEKK model proposed by Engle and Kroner (1995) will be used.[7] This type of model allows unrestricted time-varing variances and covariances, it can also be modified to include asymmetries (Kroner and Ng (1998)).[8] The model to be estimated takes the form:

$$Y_{t+1} = A + \sum_{i=1}^{p} B_i Y_{t+1-i} + \sum_{j=1}^{N_I} \Phi_j H_{[1:N,j],t+1} + \epsilon_{t+1} \tag{9}$$

where $Y_{t+1}$ is an $Nx1$ vector of dependent variables in which the first $N_1$ elements are assumed to be the excess returns, $A$ is an $Nx1$ vector, $B$ and $\Phi$ are $NxN$ matrices, $H_{[1:N_J],t+1}$ is the $Nx1$ jth column of the conditional covariance matrix.

The first $N_1$ elements satisfy the no-arbitrage condition. The equity risk premium is given by the first $N_1$ columns of $\sum_{j=1}^{N_I} \Phi_j H_{[1:N_J],t+1}$. Thus, the corresponding rows of $B$ are restricted to be zero. The other three equations have no in-mean effects but have VAR effects.[9]

In the model we have only one risky asset, the log excess return of the Mexican stock market ($i^e$) and three macroeconomic factors: the log inflation rate ($\pi$), the log first difference of money M1 ($\triangle m$) and the log first difference of industrial production ($\triangle y$). Hence $Y_{t+1} = \left\{ i^e_{t+1}, \pi_{t+1}, \triangle m_{t+1}, \triangle y_{t+1} \right\}$. The first row of $\Phi$ appears only in the excess return equation, the other elements of $\Phi$ don't appear in the equations for the macro variables and therefore are restricted to be zero.

I performed a four variable vector autoregression and tested for the optimal lag structure, using the Schwarz information criterion. As shown in Table A1.1, the optimal lags to use in the model is $p = 1$, so the model can be expressed as:

$$Y_{t+1} = A + BY_t + \Phi H_{[1:N:1],t+1} + \epsilon_{t+1} \tag{10}$$

[7] BEKK stands for Baba Engle, Kraft and Kroner.

[8] In Appendix 2, I estimate a more restrictive model (the diagonal BEKK) to compare the goodness of fit of the chosen model.

[9] In a vector autoregression, the dependent variables depend on its own lag and lags of the other variables.

where only the first row of $B$ is restricted to be zero. The specification of the innovation process is:

$$\epsilon_{t+1} = H_{t+1}^{1/2} u_{t+1} \qquad u_{t+1} \sim \mathbb{N}(0,1)$$

and the conditional variance covariance matrix with asymmetries is specified by:[10]

$$H_{t+1} = CC' + DH_tD' + E\varepsilon_t\varepsilon_t'E' + G\eta_t\eta_t'G' \tag{11}$$

where the conditional variance covariance matrix takes the form:

$$H_{T+1} = \begin{bmatrix} H_{11} & H_{12} & H_{13} & H_{14} \\ H_{21} & H_{22} & H_{23} & H_{24} \\ H_{31} & H_{32} & H_{33} & H_{34} \\ H_{41} & H_{42} & H_{43} & H_{4} \end{bmatrix},$$

where, $H(i,i)$ is the variance of variable $i$ and $H(i,j)$ is the covariance of variables $i$ and $j$.

The asymmetry is due to the term in $\eta_t = min[\varepsilon_t, 0]$. From equation (11), the eigenvalues are:

$$(D \otimes D) + (E \otimes E) + (G \otimes G)$$

which must lie inside the unit circle for the BEKK system to be stationary.[11] Equation (6) is estimated using the maximum likelihood estimator proposed by Bollerslev (1990).[12]

The equity risk premium can be decomposed into the components associated with the three macroeconomic factors. The equity risk premium can be re-written as:

[10] The equation for the conditional variance is different from the one used by Smith, Sorensen and Wickens (2010). I use the original model proposed by Kroner and Ng (1998).

[11] $\otimes$ is the Kronecker product.

[12] The log likelihood function takes the form: $\ell(\theta) = -(TN/2)\, log\, 2\pi - (1/2) \sum_{t=1}^{T} (log\,|H_t| + \epsilon_t' H_t^{-1} \epsilon_t)$.

$$\phi_t = \phi_{exces\,return,t} + \phi_{inflation,t} + \phi_{output,t} + \phi_{money,t} \tag{12}$$

where $\phi_{jt}$ is the covariance between the jth macroeconomic factor and the excess return. Another possible way to decompose the equity risk premium allows us to determine the importance of asymmetries. The conditional variance-covariance matrix has four components:

$$H_{t+1} = H_0 + H_{1,t+1} + H_{2,t+1} + H_{3,t+1}.$$

Further, $\Phi H_{t+1}$ gives the decomposition:

$$\phi_t = \phi_0 + \phi_{1,t} + \phi_{2,t} + \phi_{4,t}. \tag{13}$$

In equation (13), the equity risk premium $\phi_t$ is separated by its conditional variance components: $\phi_{1,t}$ is the part of the equity risk premium due to autoregressive effects, $\phi_{2,t}$ is the component due to ARCH effects and $\phi_{3,t}$ is the component due to asymmetries.

# 3 Estimations

## 3.1 Data

I use monthly data for the period January 1993 to December 2013. The stock market returns are the log value-weighted return on all stocks listed on the Mexican stock exchange (BMV) and were taken from Bloomberg.[13] The risk-free rate is the 28 day CETES yield taken from Banco de México.[14] The macroeconomic variables are inflation, the index of industrial production, both obtained from INEGI, and M1 obtained from

[13] The log value-weighted return is calculated as follows: $R_t = \sum_{i=1}^{n} w_{it-1} R_{It}$, where $R_t = ln(P_{T+1}/P_t)$ and $w_{it}$ is the market capitalization of firm i at time t.

[14] CETES are Mexican treasury certificates.

Banco de México.

For production I took the log of the seasonally adjusted series of the index of industrial production (IPI), inflation is the log first difference of CPI and money growth is the log first difference of M1.

Table 1 shows periods of recession during the sample period. In Figure 1 we can clearly see the picks and troughs of the business cycle in Mexico. We start with the 1992-1993 recession which was moderate, then a brief period of expansion before the tequila crisis hit the economy. During this time, the IPI touched the lowest level for the period in the sample. Right after the crisis passed, Mexico observed a four year period of expansion which were the fastest growing years for the observed period. The third recession was the so-called "dot-com bubble".[15] This bubble was followed by a period of moderate expansion and then the fourth recession began with the 2008 financial crisis during which Mexico's GDP fell by 6.5% (INEGI).

[15]This was a historic speculative bubble generated in the U.S. with its climax on March 2000. Ljungqvist and Wilhelm (2003) for more details.

Table 1: Recession dates.

| 1993m01-1993m11 | 1994m11-1995m10 | 2000m10-2003m09 | 2008m01-2009m05 |
|---|---|---|---|
| 11 | 12 | 36 | 17 |

number of observations: 76

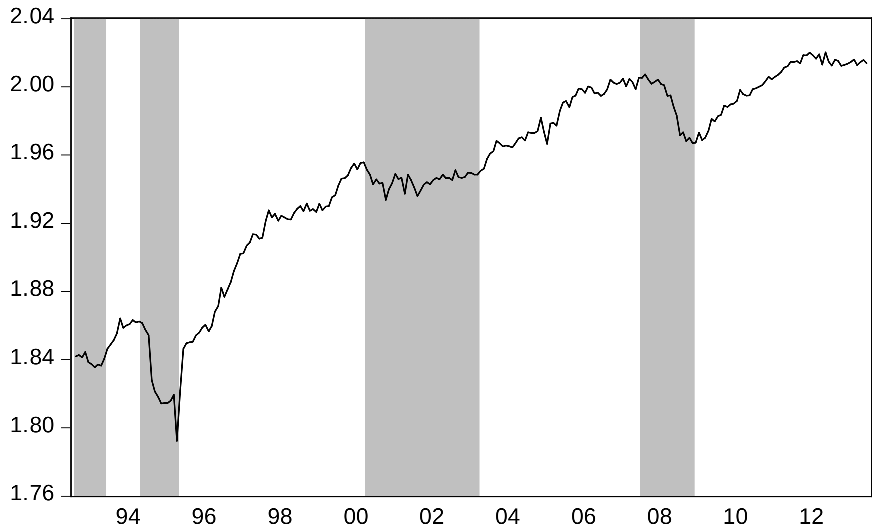


Figure 1: Production.

Among the four recessions mentioned above, there are two financial crises, the 1994 Mexican financial crisis and the 2008 U.S. financial crisis. I will focus the analysis on these two crisis. The origins of Mexico's crisis were: a large scale of deregulation in the economy, trade and capital flow liberalization, fixing the value of the Mexican peso to the dollar, weak regulation of banks and investor´s enthusiasm. All of these factors combined with political and social instability led to the worst recession in Mexico's history (Musacchio, 2012). For the 2008 financial crisis, the origins were: an asset price bubble that interacted with new kinds of financial innovations that masked risk, companies that failed to follow their own risk management procedures and weak regulation and supervision that failed to restrain excessive risk taking, (Baily, Litan and Johnson, 2008).

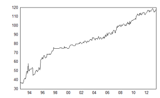

Figure 2: Excess return.
Note.*Shaded areas are recessions.*

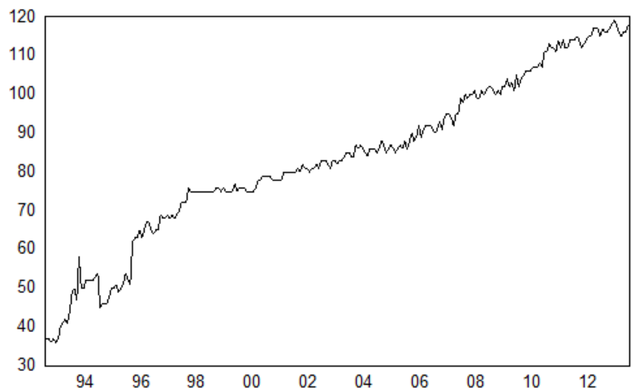


Figure 3: Evolution of number of firms listed on the Mexican stock exchange.

In Figure 2 we can see the "jumps" of excess return during recessions. It is not surprising since as we have seen when risk is higher, the equity risk premium also has to be higher. We can also see that during recessions the variation of return is much higher and that there is an asymmetric effect of positive and negative shocks. Excess returns display periods of turbulence and tranquility suggesting volatility clustering. In Figure 3 the evolution of firms listed on the Mexican stock market is shown. This is important because it might help explain the higher variation or returns during early years of the sample.

In Figure 4, inflation is depicted. We can clearly see the stabilization of this macro variable from the year 2000 when the Mexican central bank's mandate change to inflation objectives. Also we can see the hyperinflation of 1995 right after the tequila crisis.[16]

[16] In December 1994 Mexico adopted a free floating exchange rate regime.The exchange rate depreciated 20.39% in one day (Musacchio, 2012).

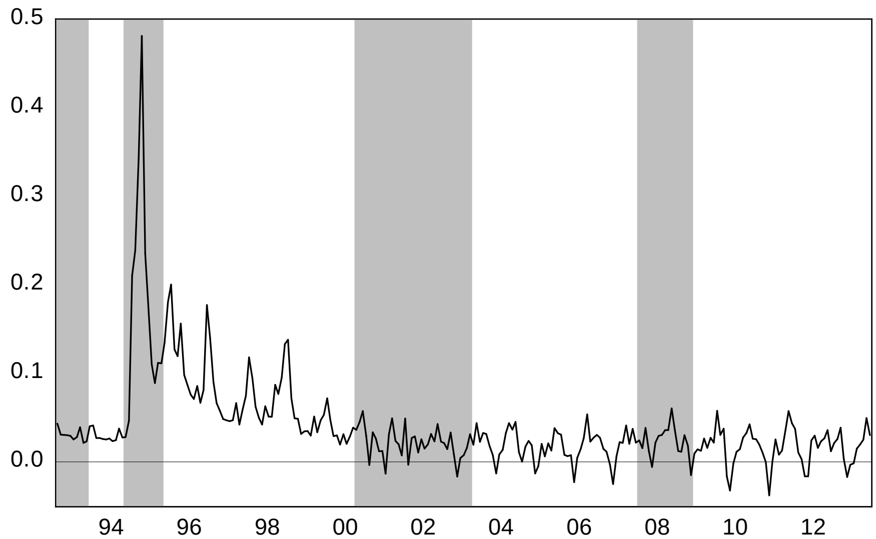


Figure 4: Inflation.

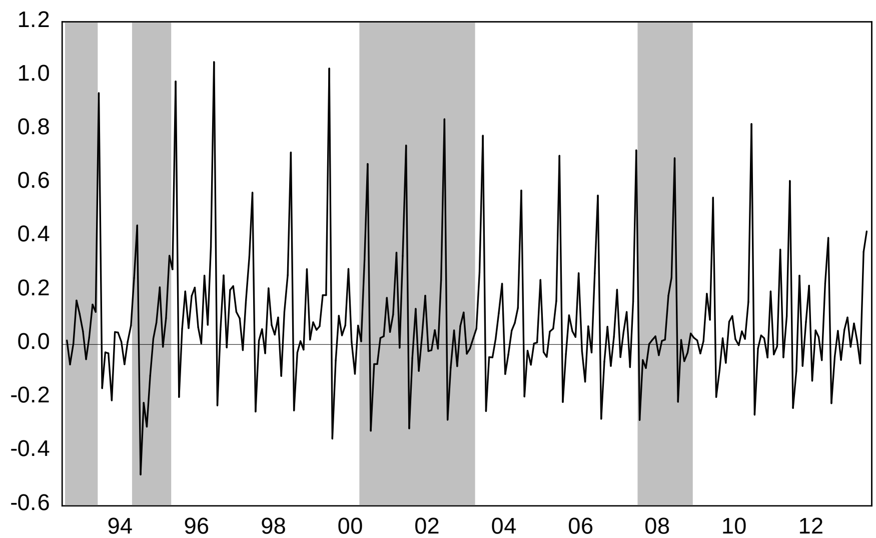


Figure 5: Money growth.

Table 2: Stationary tests.

| | ADF | DF-GLS | KPSS |
|---|---|---|---|
| variable | t-statistic | t-statistic | LM stat |
| $i_{t+1}$ | -14.289 | -3.724 | 0.1850 |
| $\pi_{t+1}$ | -2.672 | -2.181 | 0.960 |
| $\triangle M1_{t+1}$ | -15.687 | -2.187 | 0.166 |
| $\triangle Y_{t+1}$ | -4.926 | -3.559 | 0.475 |
| $Y_{t+1}$ | -1.373** | 0.988** | 1.801** |

**$H_0$of presence of a unit root in the series.
can't be rejected at 5% level.

As we can clearly see from the graphs, some of the macroeconomic series are not stationary and show a seasonal component. For that reason, I perform an augmented Dickey-Fuller (ADF) unit root test and a seasonality test on all variables.

As shown in Table 2, for excess return, inflation and money growth, the null hypothesis of existence of a unit root in the series is rejected but that is not the case for the production variable where there is evidence of a unit root in the series. For that reason I take the first difference of the series and test again for the presence of a unit root. I find that the log first difference of production is stationary. Then I perform two other different tests: the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) and DF-GLS unit root tests.[17]All results were confirmed.

In Table 3 the test for seasonality is shown. As you can also predict from looking at the graphs, inflation and money growth show a seasonal behavior. To prevent possible biases in estimation I perform a X-12 ARIMA to adjust the series. After a new test I find that there is no evidence of seasonality in the series.[18]

[17]KPSS is used for testing a null hypothesis that an observable time series is stationary around a deterministic trend. The DF-GLS unit root test is a Dickey and Fuller applied to the regression residual, which arises from the generalized least squares (Vougas, 2007).

[18]I also performed a Kruskal-Wallis test. The null hypothesis of the Kruskal-Wallis test states that stable seasonality is present in the time series, is rejected if the p-value is higher than 5%.

X-12 ARIMA is a software package for seasonal adjustment from the U.S. Census Bureau which is part of the software E-views8®.

Table 3: Test for the presence of seasonality.

| variable | F-statistic | KW-statistic |
|---|---|---|
| $i_{t+1}$ | 1.315 | 19.623 |
| $\pi^{\diamondsuit}_{t+1}$ | 5.08* | 82.394* |
| $\pi_{t+1}$ | 0.782 | 6.990 |
| $\triangle M1^{\diamondsuit}_{t+1}$ | 146.197* | 181.936* |
| $\triangle M1_{t+1}$ | 0.459 | 1.689 |
| $\triangle Y_{t+1}$ | 1.252 | 5.490 |

*Seasonality present at the 1 per cent level.

KW: Kruskal-Wallis.

$\diamondsuit$: before X12 ARIMA.

In Table 4, we present descriptive statistics for the four stationary and seasonally adjusted variables and in Table 5 the cross-correlation of the variables. All four variables show positive skewness, excess kurtosis and reject normality using a 0.99 confidence interval. Excess return has significant first order autocorrelation, also autocorrelation in squared returns and absolute returns. Autocorrelation presence indicates that volatility of excess return is partly predictable and there is also evidence of asymmetries in the volatility process. This indicates the possible presence of ARCH effects.

Inflation shows strong and very significant autocorrelation, the same for squared and absolute inflation. Production shows weak autocorrelation with previous months but that changes with respect to the previous trimester. Autocorrelation in squared production and absolute production is also significant. Money growth shows close to zero skewness which means little or no asymmetries in its distribution, and very strong and highly significant first order autocorrelation, squared autocorrelation and absolute autocorrelation.

Table 4: Descriptive statistics

| | $i_{t+1}$ | $\pi_{t+1}$ | $\triangle Y_{t+1}$ | $\triangle M1_{t+1}$ |
|---|---|---|---|---|
| Mean | 0.137398 | 0.040302 | 0.010294 | 0.084701 |
| Std.dev | 0.381964 | 0.049273 | 0.061498 | 0.090276 |
| Skewness | 1.624852 | 3.752575 | 0.971463 | 0.007389 |
| kurtosis | 12.45173 | 24.48912 | 15.83326 | 5.885677 |
| Normality | 1044.744 | 5418.56 | 1761.89 | 87.0902 |
| $\rho(x_t, x_{t-1})$ | 0.097* | 0.882* | 0.007 | 0.092* |
| | (2.3979) | (197.53) | (0.0119) | (2.1428) |
| $\rho(x_t, x_{t-2})$ | -0.062* | 0.762* | 0.006 | 0.242* |
| | (3.3905) | (345.53) | (0.0224) | (17.124) |
| $\rho(x_t, x_{t-3})$ | 0.001* | 0.649* | 0.045 | 0.386* |
| | (3.3907) | (453.36) | (0.547) | (55.271) |
| $\rho(x_t, x_{t-4})$ | 0.063* | 0.555* | 0.14* | 0.052* |
| | (4.4149) | (532.48) | (5.5761) | (55.958) |
| $\rho(x_t, x_{t-5})$ | -0.084* | 0.545* | 0.043* | 0.147* |
| | (6.2274) | (609.12) | (6.0486) | (61.509) |
| $\rho(x_t, x_{t-6})$ | -0.099* | 0.537* | 0.019* | 0.193* |
| | (8.769) | (683.75) | (6.1458) | (71.115) |
| $\rho(x_t, x_{t-12})$ | -0.019* | 0.332* | -0.07* | -0.047* |
| | (10.998) | (1000.7) | (12.746) | (82.645) |
| $\rho(x_t^2, x_{t-1}^2)$ | 0.081 | 0.686* | -0.58* | 0.052 |
| | (1.675) | (119.71) | (85.314) | (0.6786) |
| $\rho(x_t^2, x_{t-2}^2)$ | -0.007 | 0.457* | 0.132* | 0.096* |
| | (1.689) | (172.89) | (89.757) | (3.0304) |
| $\rho(x_t^2, x_{t-3}^2)$ | 0.012 | 0.3* | -0.032* | 0.289* |
| | (1.7268) | (195.89) | (90.017) | (24.38) |
| $\rho(x_t^2, x_{t-4}^2)$ | 0.107* | 0.192* | -0.035* | 0.062* |
| | (4.6716) | (205.4) | (90.338) | (25.372) |
| $\rho(x_t^2, x_{t-5}^2)$ | 0.05* | 0.189* | -0.04* | 0.079* |
| | (5.3237) | (214.59) | (90.741) | (26.965) |
| $\rho(x_t^2, x_{t-6}^2)$ | 0.051* | 0.196* | -0.027* | 0.251* |
| | (5.9894) | (224.57) | (90.928) | (43.26) |
| $\rho(x_t^2, x_{t-12}^2)$ | 0.007* | 0.091* | 0.013* | 0.085* |
| | (6.3941) | (257.79) | (111.77) | (68.958) |
| $\rho(\|x\|_t, \|x\|_{t-1})$ | 0.265* | 0.883* | 0.45* | 0.069 |
| | (17.842) | (198.02) | (51.528) | (1.2115) |
| $\rho(\|x\|_t, \|x\|_{t-2})$ | 0.089* | 0.765* | 0.143* | 0.161* |
| | (19.854) | (347.27) | (56.772) | (7.8508) |
| $\rho(\|x\|_t, \|x\|_{t-3})$ | 0.11* | 0.655* | -0.053+ | 0.364* |
| | (22.979) | (457.15) | (57.479) | (41.716) |
| $\rho(\|x\|_t, \|x\|_{t-4})$ | 0.204* | 0.563* | -0.045* | 0.114* |
| | (33.641) | (538.62) | (57.996) | (45.077) |
| $\rho(\|x\|_t, \|x\|_{t-5})$ | 0.102* | 0.555* | -0.1* | 0.098* |
| | (36.346) | (618.09) | (60.573) | (47.58) |
| $\rho(\|x\|_t, \|x\|_{t-6})$ | 0.131* | 0.548* | -0.011* | 0.231* |
| | (40.767) | (695.84) | (60.607) | (61.435) |
| $\rho(\|x\|_t, \|x\|_{t-12})$ | 0.024* | 0.356* | 0.04* | 0.124* |
| | (50.382) | (1028.6) | (86.539) | (103.98) |

* Significant at 1 per cent level.

Table 5: Cross-correlations.

| | $i_{t+1}$ | $\pi_{t+1}$ | $\triangle Y_{t+1}$ | $\triangle M1_{t+1}$ |
|---|---|---|---|---|
| $i_{t+1}$ | 1 | | | |
| $\pi_{t+1}$ | 0.1594** | 1 | | |
| | (2.549) | | | |
| $\triangle Y_{t+1}$ | 0.0489 | -0.0310 | 1 | |
| | (0.773) | (-0.4888) | | |
| $\triangle M1_{t+1}$ | 0.0457 | 0.0638 | 0.2079** | 1 |
| | (0.7218) | (1.0087) | (3.3543) | |

t-statistics in parenthesis.

** Coss-correlation is significant at 5 per cent level.

Table 5 shows cross-correlations of the variables. Excess return and inflation have a positive significant correlation, first order correlation between excess return and production and excess return and money growth is not significant. There is positive and significant correlation between production and money growth. Inflation and production have negative but insignificant correlation. Results for all variables change significantly when taking cross-correlation of lagged values of the series. There is strong evidence of cross-correlation between all series.[19] This is important evidence for the use of a multivariate GARCH model because lagged values conditional variance of all series affect each other.

In Table 6, descriptive statistics of the variables are separated into into two periods, recessions and other periods. This shows that the average excess return during recessions is almost half of the return observed in every other period. For the macroeconomic factors, as expected, production growth is negative money growth is smaller and inflation is lower during recessions. Correlations between macroeconomic variables and excess return are very significant and this is more evidence of the importance of the business cycle on stock returns.

[19]See Appendix 1 Tables A1.8-A1.13 for further details.

Table 6: Descriptive statistics: recessions vs other periods.

| Model 2 | Excess return | Inflation | Production | Money | Equity risk premium |
|---|---|---|---|---|---|
| Mean in recessions | 0.0473 | 0.0149 | -0.0046 | 0.0210 | 0.0495 |
| Mean elsewhere | 0.0901 | 0.0254 | 0.0149 | 0.0637 | 0.0776 |
| Correlation with excess return in recessions | 1 | 0.3301 | -0.1594 | 0.1935 | |
| | | (5.508)* | (2.543)* | (3.107)* | |
| Correlation with excess return elsewhere | 1 | 0.4077 | -0.0262 | -0.6581 | |
| | | (1.729) | (0.102) | (3.385)* | |
| Mean conditional SD in recessions | 0.0087 | 0.0160 | 0.0335 | 0.1023 | |
| Mean conditional SD elsewhere | 0.0190 | 0.0360 | 0.0777 | 0.2193 | |
| Mean contribution to risk in recessions | 0.0820 | -0.0086 | -0.0282 | 0.0042 | 1 |
| Mean contribution to risk elsewhere | 0.1468 | -0.0174 | -0.0610 | 0.0092 | 1 |

*Significant at 1 per cent level.

Table 7: Test for ARCH effects.

| | $i_{t+1}$ | | $\pi_{t+1}$ | | $\triangle M1_{t+1}$ | | $\triangle Y_{t+1}$ | |
|---|---|---|---|---|---|---|---|---|
| variable | F-stat | LM-stat | F-stat | LM-stat | F-stat | LM-stat | F-stat | LM-stat |
| lag (1) | 3.99** | 3.95** | 148.35* | 93.44* | 125.07* | 83.7* | 3.4*** | 3.38*** |
| lag (2) | 2.06 | 4.10 | 73.88* | 93.3* | 79.68* | 97.74* | 2.53 | 5.01 |
| lag (4) | 1.25 | 4.98 | 37.23* | 93.96* | 39.5* | 97.43* | 3.74 | 14.38 |
| lag (6) | 0.90 | 5.41 | 33.02* | 111.10* | 26.22* | 97.34* | 2.74 | 15.80 |
| lag (8) | 0.72 | 5.86 | 24.38* | 110.28* | 21.61* | 103.07* | 2.08 | 16.11 |
| lag (12) | 0.48 | 5.89 | 17.4* | 114.56* | 15.29* | 106.91* | 1.40 | 16.56 |

*The Ho of no presence of ARCH effects is rejected at 1 per cent level.

**The Ho of no presence of ARCH effects is rejected at 5 per cent level.

***The Ho of no presence of ARCH effects is rejected at 10 per cent level.

The last step before estimation is to test for ARCH effects in residuals of the series. I perform a Lagrange multiplier (LM) test for heteroskedasticity in squared residuals. In Table 7 results are shown for the LM and F test with 1, 2 , 4 , 6, 8 and 12 lags for each of the series. The null hypothesis of no ARCH effects is rejected at the 5 per cent level for excess return, at the 10 per cent level for money growth and at the 1 per cent level for inflation and output.

In sum, from the data there is strong evidence for the use of a multivariate GARCH-in-mean since there is clear presence of ARCH effects in the series, significant cross-correlations and lagged cross-correlations between the series, non-normality, skewness and serial correlation.

## 3.2 Results

Following Smith, Sorensen and Wickens (2010), seven different versions of equation (10), the no-arbitrage equation, are estimated in order to separate the effects of the covariances of the three macroeconomic factors with the excess return. Only the corresponding equation for excess return as dependent variable will be modified and estimated. The remaining three equations for the macroeconomic variables as dependent variables will not be modified.

Model 1 is the benchmark Capital Pricing Asset Model (CAPM) which relates the expected excess return with only one factor, the volatility of excess return and assumes a conditional covariance between inflation and excess return equal to one.

Model 2 is a more general version with all three macroeconomic factors and the conditional variance of excess return.

Models 3 to 6 price only the macroeconomic factors and do not take into account the conditional variance of the excess return component with models 4 to 6 pricing each macroeconomic factor individually. Model 7 is used as a verification of model 1 (CAPM) which restricts the conditional covariance between inflation and excess return equal to one. Model 7 allows for this coefficient to be different than one.

In Table 8, the estimates of all seven models are displayed. The two models with less explanatory power are models 4 and 5 as measured by both the log-likelihood and the share of conditional excess return variance explained by the variance of equity risk premium; they also have the highest mean residuals. These two models seek to explain the excess return with its conditional covariance with inflation and production.

For the Mexican data, I find that the coefficient of covariance between inflation and excess return is not significant, this is verified by the fact that the model 4 has very little explanatory power, this suggest that inflation has a very different impact on excess return than model 1 predicts.

Model 2 includes all three macroeconomic factors. It has the lower residual and has the higher excess return variance explanatory power. There is strong evidence that including macroeconomic variables helps to explain excess return more than the traditional CAPM model.

Model 3 does not include excess return variance and therefore has very little explanatory power and the average residual is almost three times bigger in model 3 than in model

2, inflationa and insdustrial are significantly priced but the sign of conditional covariance of excess return and inflation is now negative.

Models 4 to 6 include only one macroeconomic factor. All three of them explain around 2% of excess return variance, which is very low, but are very significantly priced, except for money growth.

Tables 9a and 9b report estimates for the more general model 2. In matrix $\hat{B}$ we can observe the VAR effects for the macroeconomic variables, the coefficients related with their own lag are highly significant as well as the coefficient of lagged production and money on inflation and the coefficient of lagged money growth on production.

For the conditional variance equation, the autoregressive component in $\hat{D}$ is very significant in the diagonal and there is evidence that each variable helps explain the others. For the asymmetries parameter matrix $\hat{G}$, the negative sign of conditional variance indicate that negative own shocks have a lower impact than positive own shocks and the opposite happens for the macro variables.

Table 8: Model estimates.

| | M1 | M2 | M3 | M4 | M5 | M6 | M7 |
|---|---|---|---|---|---|---|---|
| $V_t(i_{t+1})$ | 153.068* | 263.73* | | | | | 154.610* |
| | (2.08) | (6.54) | | | | | (4.06) |
| $Cov_t(i_{t+1}, \pi_{t+1})$ | 1 | 107.141* | -29.191* | -288.302* | 1 | 1 | 6.932* |
| | | (8.65) | (7.96) | (5.64) | | | (7.96) |
| $Cov_t(i_{t+1}, \triangle Y_{t+1})$ | | -180.29* | -40.413* | | 135.658* | | |
| | | (5.79) | (4.64) | | (3.13) | | |
| $Cov_t(i_{t+1}, \Delta M1_{t+1})$ | | 2.68 | 25.951 | | | 23.958 | |
| | | (0.87) | (0.65) | | | (0.35) | |
| Log-likelihood | -27963 | -27095 | -28258 | -29375 | -29804 | -28333 | -27963 |
| Average residual | 0.1296 | 0.1275 | 0.1026 | 0.066 | 0.060 | 0.107 | 0.1296 |
| Risk share (%) | 8.50 | 12.22 | 2.50 | 2.03 | 2.77 | 2.29 | 8.67 |

Risk share: 100*Var($\varphi$)/Var(excess return+1/2V(excess return).

t-statistic in parenthesis.

Table 9a: Model 2.

$$Y_{t+1} = A + B_i Y_t + \Phi_J H_{[1:N_1],t+1} + \epsilon_{t+1}$$

$$\epsilon_{t+1} = H_{t+1}^{1/2} u_{t+1} \qquad u_{t+1} \sim \mathbb{N}(0,1)$$

$$H_{t+1} = CC' + DH_tD' + E\varepsilon_t\varepsilon_t'E' + G\eta_t\eta_t'G'$$

$$\hat{A} = \begin{bmatrix} 0 \\ 0.0062 \\ {\scriptstyle (1.313)} \\ -0.051 \\ {\scriptstyle (4.565)} \\ 0.0547 \\ {\scriptstyle (2.023)} \end{bmatrix},$$

$$\hat{\Phi} = \begin{bmatrix} 263.7349 & 107.415 & -180.293 & 2.683 \\ {\scriptstyle (40.275)} & {\scriptstyle (12.414)} & {\scriptstyle (-31.092)} & {\scriptstyle (3.072)} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix},$$

$$\hat{B} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0.0271 & 0.8277 & -0.3271 & 0.0965 \\ {\scriptstyle (3.129)} & {\scriptstyle (10.888)} & {\scriptstyle (4.379)} & {\scriptstyle (2.755)} \\ 0.0180 & 0.5195 & 0.0758 & 0.2493 \\ {\scriptstyle (0.934)} & {\scriptstyle (3.191)} & {\scriptstyle (0.6173)} & {\scriptstyle (0.6173)} \\ -0.7976 & 3.3783 & 3.458 & -1.506 \\ {\scriptstyle (14.455)} & {\scriptstyle (8.164)} & {\scriptstyle (10.48)} & {\scriptstyle (7.482)} \end{bmatrix},$$

$$\hat{D} = \begin{bmatrix} 0.9450 & -0.0164 & -0.0141 & 0.0117 \\ {\scriptstyle (9.813)} & {\scriptstyle (0.209)} & {\scriptstyle (0.039)} & {\scriptstyle (0.057)} \\ 0.0051 & 0.9457 & -0.0059 & 0.0016 \\ {\scriptstyle (0.120)} & {\scriptstyle (12.525)} & {\scriptstyle (0.089)} & {\scriptstyle (0.034)} \\ 0.0088 & 0.0067 & 0.9455 & 0.0080 \\ {\scriptstyle (0.022)} & {\scriptstyle (0.038)} & {\scriptstyle (3.110)} & {\scriptstyle (0.050)} \\ -0.0020 & 0.0142 & -0.0005 & 0.9461 \\ {\scriptstyle (0.008)} & {\scriptstyle (0.060)} & {\scriptstyle (0.037)} & {\scriptstyle (92.757)} \end{bmatrix}$$

Table 9b: Model 2.

$$\hat{E} = \begin{bmatrix} \underset{(0.019)}{-0.0089} & \underset{(0.037)}{0.0071} & \underset{(0.024)}{0.0038} & \underset{(0.021)}{-0.0107} \\ \underset{(0.014)}{-0.0037} & \underset{(0.028)}{-0.0094} & \underset{(0.157)}{-0.0103} & \underset{(0.237)}{0.0328} \\ \underset{(0.031)}{0.0083} & \underset{(0.007)}{0.0044} & \underset{(0.038)}{-0.0008} & \underset{(0.022)}{0.0028} \\ \underset{(0.050)}{0.0102} & \underset{(0.192)}{-0.0235} & \underset{(0.347)}{0.0266} & \underset{(0.032)}{0.0203} \end{bmatrix},$$

$$\hat{G} = \begin{bmatrix} \underset{(0.065)}{0.1013} & \underset{(0.011)}{0.0215} & \underset{(0.031)}{0.0049} & \underset{(0.014)}{-0.0060} \\ \underset{(0.010)}{-0.0082} & \underset{(0.788)}{0.1064} & \underset{(0.029)}{-0.0025} & \underset{(0.087)}{-0.0167} \\ \underset{(0.162)}{0.0140} & \underset{(0.036)}{0.0220} & \underset{(0.035)}{0.1189} & \underset{(0.010)}{-0.0089} \\ \underset{(0.032)}{0.0171} & \underset{(0.064)}{-0.0023} & \underset{(0.029)}{0.0107} & \underset{(0.177)}{0.0996} \end{bmatrix}$$

$$\hat{C} = \begin{bmatrix} \underset{(2.286)}{0.2659} & 0 & 0 & 0 \\ \underset{(0.063)}{-0.0092} & \underset{(1.237)}{0.2817} & 0 & 0 \\ \underset{(0.114)}{-0.0351} & \underset{(0.248)}{-0.0320} & \underset{(0.637)}{0.2685} & 0 \\ \underset{(0.099)}{-0.0160} & \underset{(0.082)}{-0.0356} & \underset{(0.276)}{-0.0264} & \underset{(9.602)}{0.2823} \end{bmatrix}$$

In contrast to what is found for the Mexican data. Smith, Sorensen and Wickens (2010), find that for the U.S. the covariance between inflation and excess return is significant and stronger than CAPM model restricts. This result was found for model 7 which serves for comparison to our benchmark model. The positive and significant relationship between inflation and excess return found for the U.S. but not for Mexican data could be explained by the fact that Mexican inflation is much more volatile than American inflation, therefore changes in inflation for the U.S. data could reflect changes in economic policy and thus have a more direct impact on investors expectation of the state of the economy and future dividends or share prices than for the Mexican case.

For the general model 2. It was found for the U.S. that money growth becomes not significant when all three macroeconomic variables are included and the covariance between excess return and production growth becomes negative, this is consequence of the a strong negative relationship between production and inflation. I find that for the Mexican data, for the period of the sample, this relationship is not significant.

## 3.3 Equity risk premium

Let us recall that the stock market reward-to-risk is the equity risk premium $\phi_t$, which is the difference between the stock market return and the risk free rate. It was also showed in Section 2 that it can be decomposed into its components:

$$\phi_t = \phi_{exces\,return,t} + \phi_{inflation,t} + \phi_{output,t} + \phi_{money,t}$$

where $\phi_{jt}$ is the covariance between the jth macroeconomic factor and the excess return. This decomposition represents the first channel of transmission, through the mean.The equity risk premium can also be decomposed into the conditional variance-covariance matrix components:

$$\phi_t = \phi_0 + \phi_{1,t} + \phi_{2,t} + \phi_{4,t.}$$

We know that $\phi_{1,t}$ is the part of the equity risk premium due to autoregressive effects, $\phi_{2,t}$ is the component due to ARCH effects and $\phi_{3,t}$ is the component due to asymmetries. This decomposition represents the second channel of transmission, through volatility.

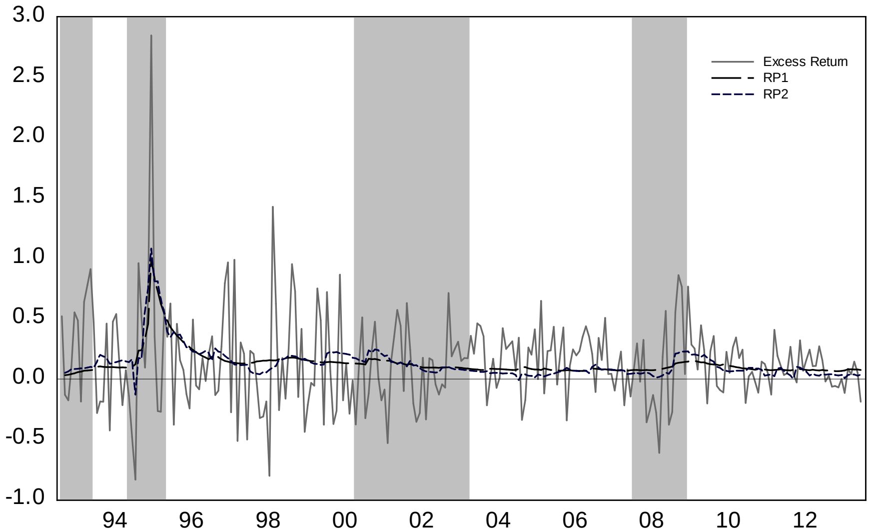


Figure 6: Equity risk premium and excess return.

Figure 6 shows the difference between the equity risk premium movements for model 1 and model 2. In model 1, the equity risk premium is only affected by the conditional variance of excess return. In model 2 the equity risk premium is affected by conditional variance of excess return and by the covariance between all three macroeconomic factors with excess return. We note that the equity risk premium from model 2 varies a lot more than the equity risk premium from model 1. An important thing to note is that the equity risk premium was negative during the tequila crisis. This means that the risk free rate was higher, in this period, than the Mexican stock market return. This translates into zero incentives to invest in the Mexican stock market and thus investors leaving from the Mexican market.

Is is also clear that the equity risk premium is higher during recessions that during expansions, suggesting is evidence of the importance of asymmetries in the model. The business cycle effect on the equity risk premium is very different in good and bad times.

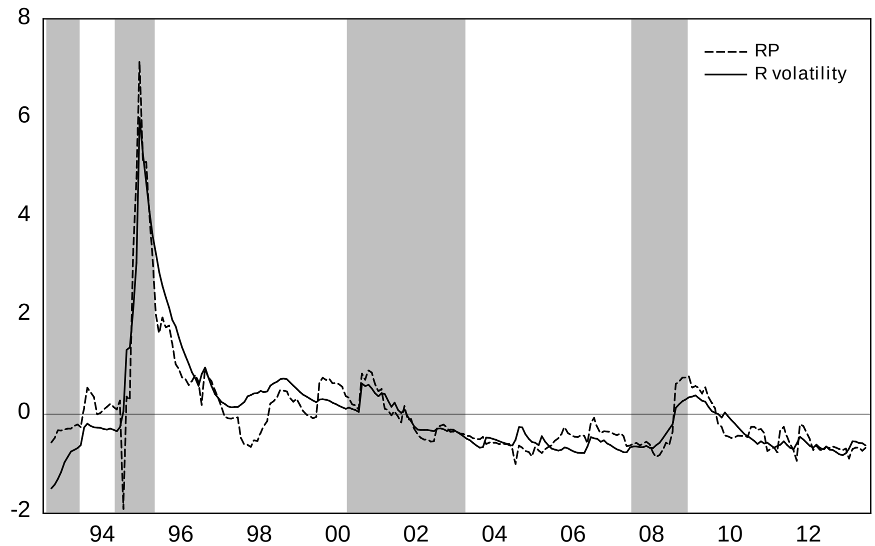


Figure 7: Equity risk premium and conditional standard deviation of excess return.

Figures 7 to 10 depict the relationship between the equity risk premium (RP) and the conditional standard deviation (volatility) of each variable.[20] In Figure 7 we find that the excess return volatility movements are very different to those of the equity risk premium and it is important to notice that the behavior during each of the four recessions is also very different. Let us focus our attention on two of them: the tequila crisis of 1994 and the recent financial crisis of 2008. Both the equity risk premium and excess return volatility reached a historical peak in 1995 with the equity risk premiums going higher than volatility. For the two subsequent recessions the effect on these two variables is considerably smaller.

For the macroeconomic variables, we can see similar behavior of the series, the peaks in volatility of each macroeconomic variable is considerably smaller during the "imported" crisis than they were during the "home made" crisis. Output varies closely with the equity risk premium; this is evidence of the strong business cycle influence on the equity risk premium.

[20] Data were normalized for this graph to be able to identify the relationship between both variables.

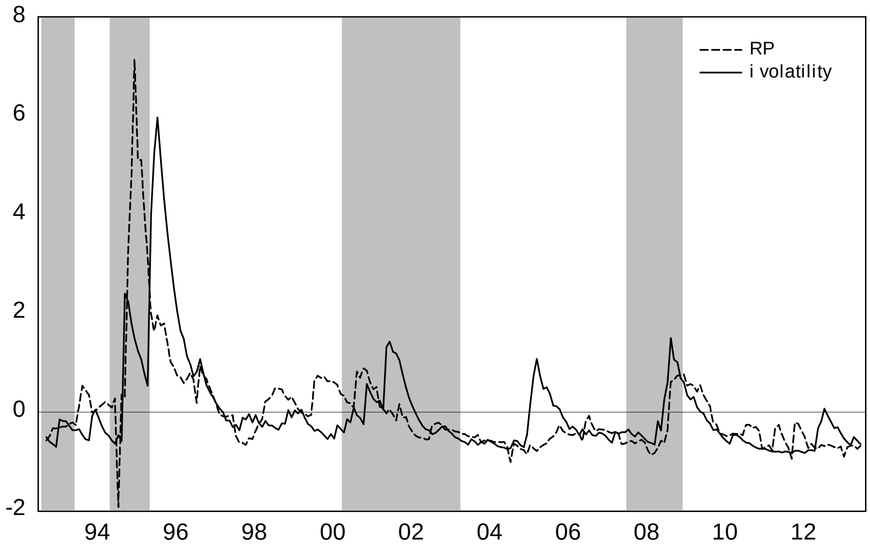


Figure 8: Equity risk premium and conditional standard deviation of inflation.

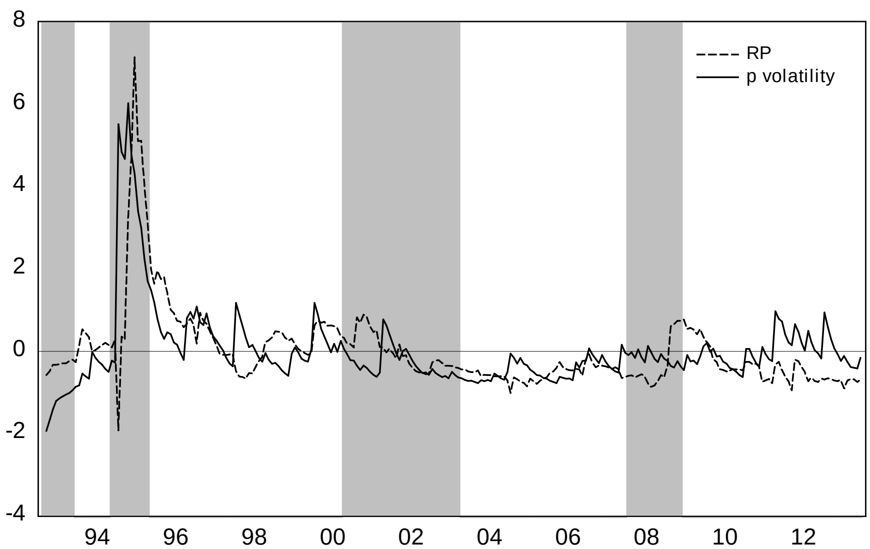


Figure 9: Equity risk premium and conditional variance of production.

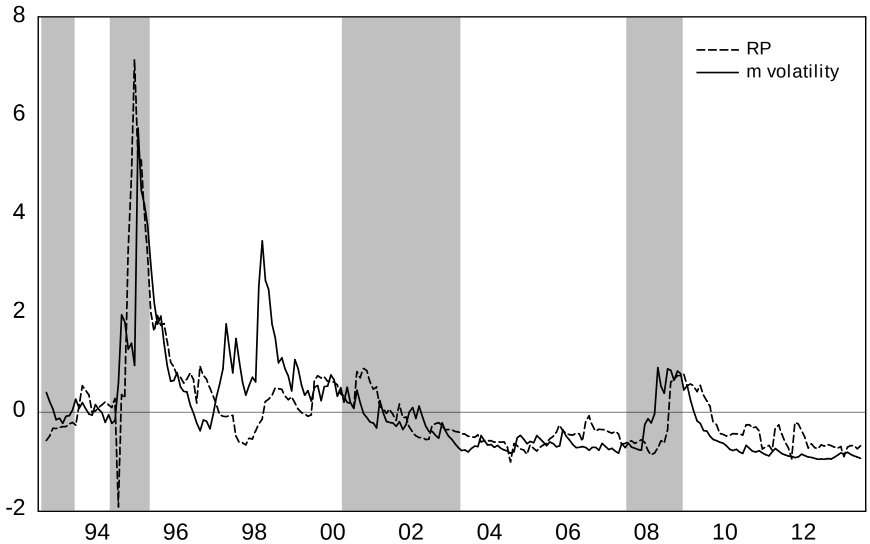


Figure 10: Equity risk premium and conditional variance of money growth.

Table 9: Equity risk premium autocorrelation.

| | $\rho_1$ | $\rho_2$ | $\rho_3$ | $\rho_4$ | $\rho_5$ | $\rho_6$ | $\rho_{12}$ |
|---|---|---|---|---|---|---|---|
| $\phi_t^{M1}$ | 0.933 | 0.850 | 0.757 | 0.675 | 0.584 | 0.504 | 0.212 |
| $\phi_t^{M2}$ | 0.914 | 0.830 | 0.684 | 0.579 | 0.469 | 0.423 | 0.238 |
| $\phi_t^{M3}$ | 0.926 | 0.834 | 0.787 | 0.762 | 0.721 | 0.664 | 0.475 |
| $\phi_t^{M4}$ | 0.813 | 0.593 | 0.447 | 0.409 | 0.381 | 0.391 | 0.249 |
| $\phi_t^{M5}$ | 0.793 | 0.593 | 0.522 | 0.529 | 0.565 | 0.467 | 0.09 |
| $\phi_t^{M6}$ | 0.945 | 0.92 | 0.88 | 0.818 | 0.782 | 0.723 | 0.479 |
| $\phi_t^{M7}$ | 0.932 | 0.848 | 0.755 | 0.672 | 0.582 | 0.502 | 0.211 |

Table 10 shows the persistence of the equity risk premium in each model, where models 3 and 6 have the most persistent equity risk premium.

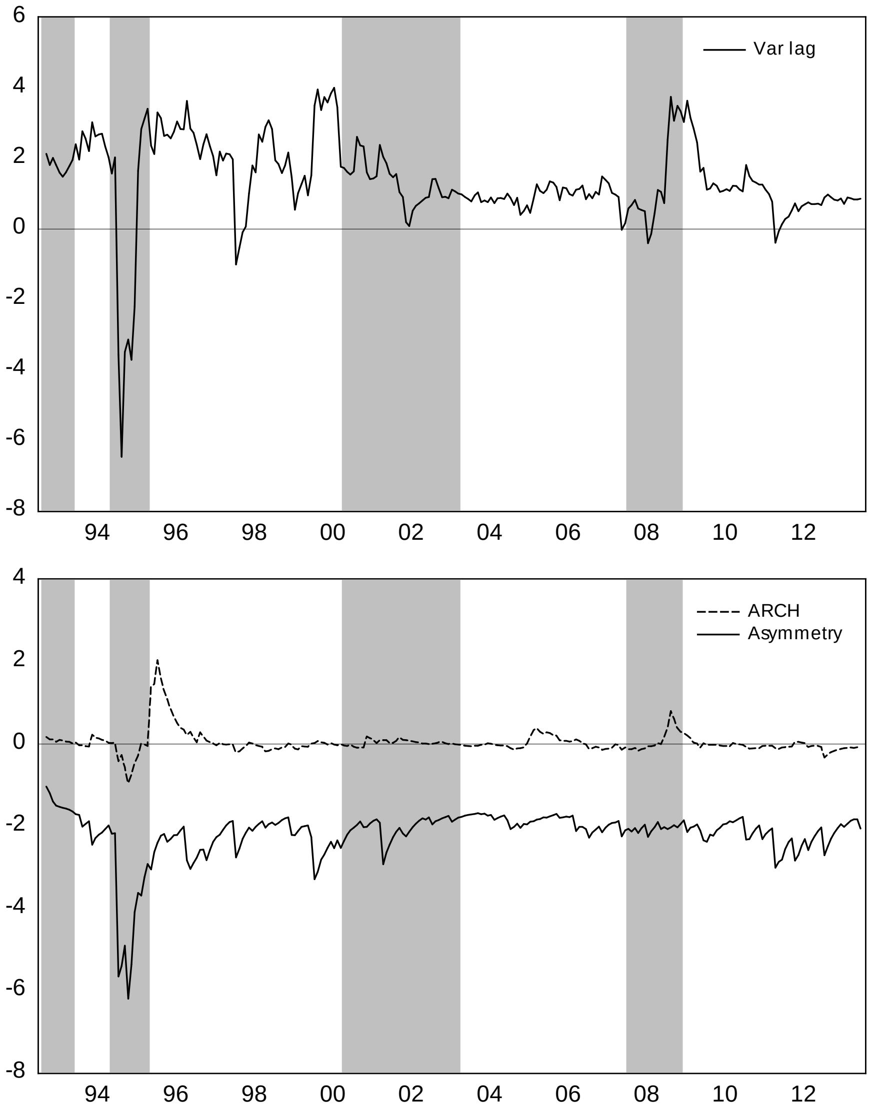


Figure 11: Contribution to risk of conditional variance components.

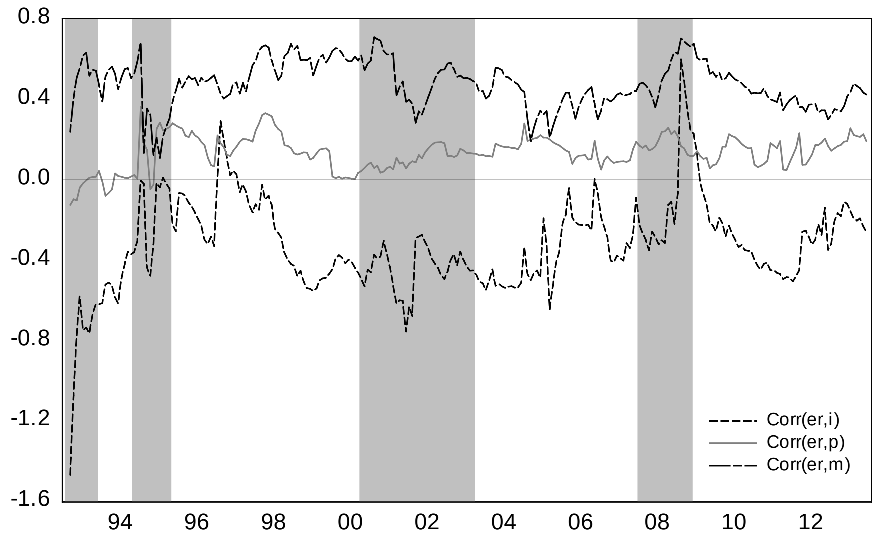


Figure 12: Conditional correlations of excess return with macroeconomic factors.

Figure 11 separates the contribution of the conditional variance components of the equity risk premium. The weaker component are the ARCH effects which are close to zero. Asymmetries are strong contributors to risk and it is the autoregressive component of variance that adds most to risk. During the tequila crisis the autoregressive component of the equity risk premium was very large and negative which suggests strong volatility clustering and that during that time, higher volatility of the previous period meant lower equity risk premium. This is very different from what we see for the 2008 financial crisis where the autoregressive component peaked.

The conditional correlation between macroeconomic factors and excess return tells us how strong is their relationship. Figure 12 illustrates that this relationship is time varying, and significantly stronger during recessions.

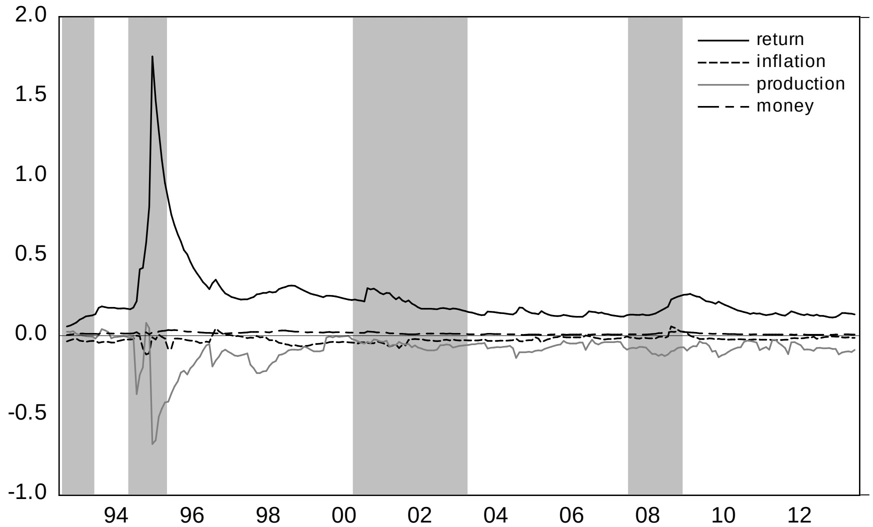


Figure 13: Contributions to risk of macroeconomic variables.

The second decomposition of the equity risk premium is the contribution of each macroeconomic factor. Again I find that the business cycle is a bigger part of the equity risk premium during downturns and that the influence of the macroeconomic factors during the tequila crisis were particularly important. This is what we should expect since this crisis was generated 100% by Mexican factors, as mentioned in Section 2.1, while the others were generated elsewhere. As we see from the plot, volatility of excess return is the factor that affects the equity risk premium the most, specially during recessions and even more when the source of the recession is Mexican. Production growth is a very important factor too in determining the equity risk premium.

### 3.4 Demand and supply shocks

In the four graphs below, I introduce a positive and negative shock of inflation and production growth and their effect on the other macroeconomic variables and the equity risk premium. I interpret inflation shocks as supply shocks and production shocks as demand shocks.

In Figure 14 a negative supply shock is introduced, the effect on the equity risk premium is positive and it lasts four months, the effect on production growth is also positive and lasts only one month. The effect on money growth is negative but not significant.

In Figure 15, in response to a positive inflation shock. The equity risk premium responds in a positive way and the effect fades 12 months later. The effect of a positive inflation shock on industrial production growth and money growth is not significant.

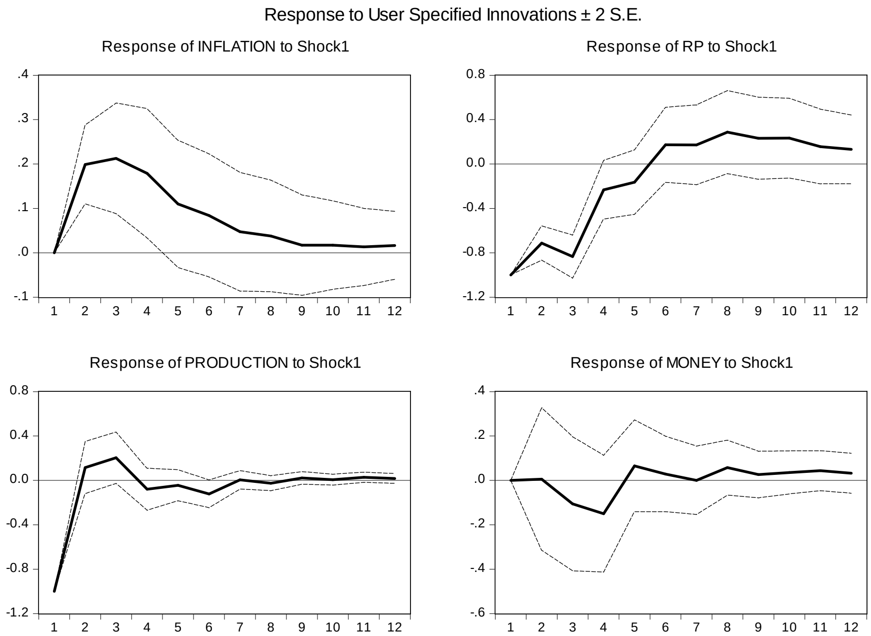


Figure 14: Negative supply shock.

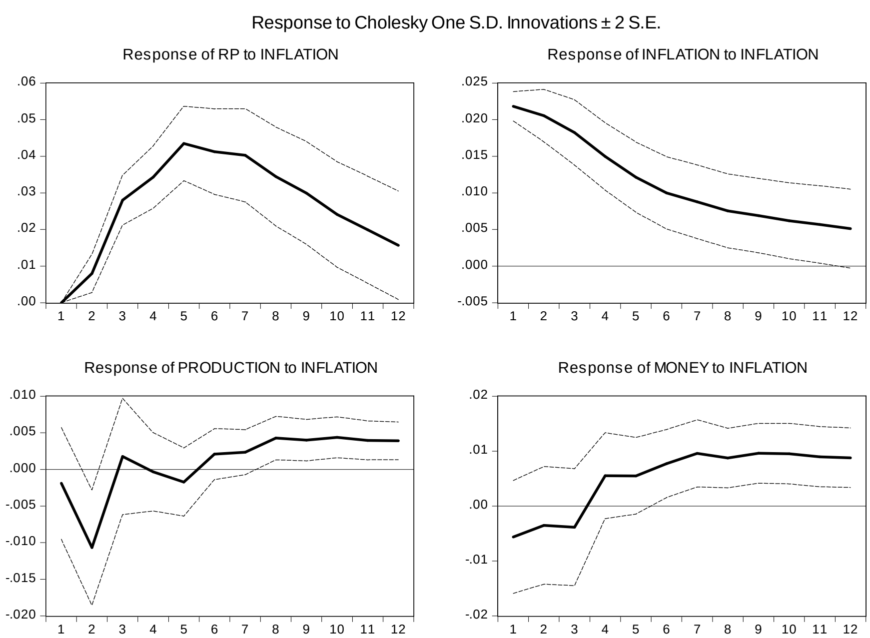


Figure 15: Positive supply shock.

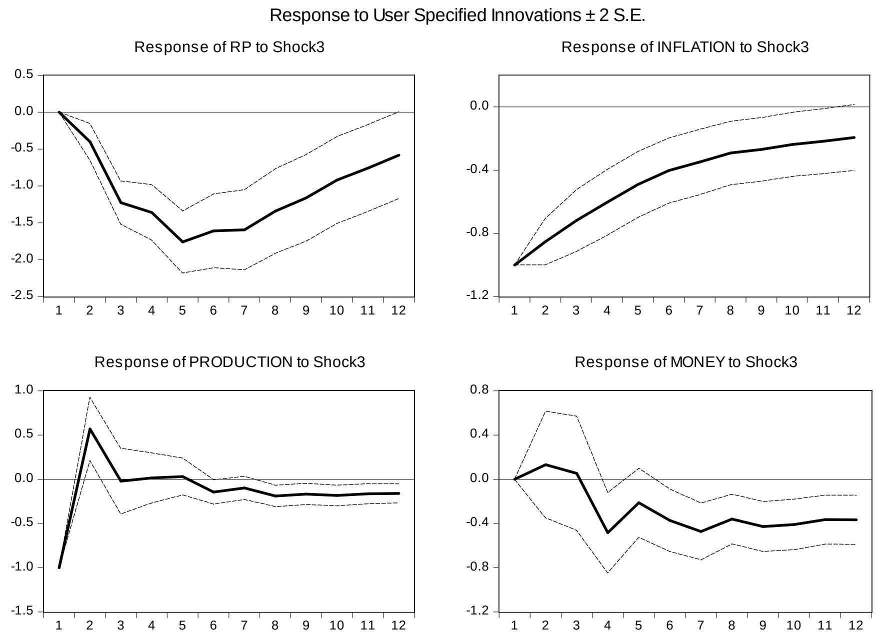


Figure 16: Negative demand shock.

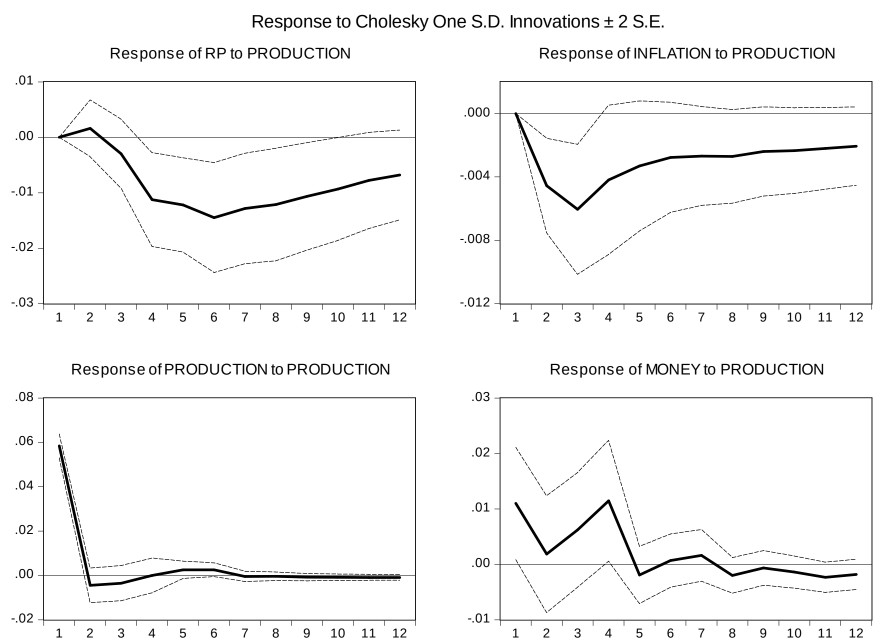


Figure 17: Positive demand shock.

Figure 16 shows the response of a negative demand shock. The equity risk premium has a negative impact that lasts for more than 12 months. Th reaction of inflation to a negative demand shock is positive and the effect takes eleven months to disappear. The impact of a negative demand shock has no significant effect on money growth.

In Figure 17 a positive demand shock is shown. The impact on the other variables is very different from the negative shock, the equity risk premium reaction to the shock is negative but not very significant. Inflation also reacts negatively and the impact disappears after three months. The reaction of money growth is negative but not significant.

In sum, there is a clear asymmetric effect of positive and negative shocks on the four variables. It is important to separate positive and negative shocks and to distinguish the source of the shock to be able to predict the possible impact on the equity risk premium since the asymmetric effect changes when the source of the impact is different. Positive supply shocks and negative demand shocks have a stronger effect on all variables and the effect es more permanent compared to negative supply shocks and positive demand shocks.

# 4 Conclusions

This thesis has found strong and significant evidence of the influence of the business cycle on the excess returns of the Mexican stock market. The transmission mechanism operates via two channels: the mean effect via the equity risk premium and the volatility effect via the conditional variance covariance matrix. The first effect is determined by the macroeconomic components of the equity risk premium and the volatility effect is determined by ARCH effects, asymmetric effects and autoregressive effects. The most important macroeconomic components of the equity risk premium are the conditional variance of excess return and the conditional covariance between excess returns and production growth. The most important component of the conditional variance was found to be the observed conditional variance from a previous period.

We also found that conditional volatility of our four variables: excess return, inflation, production and money have an effect on excess return through the equity risk premium. This result contrast to recent findings for the U.S. where only inflation and production influence the excess return through the mean.

The tequila crisis which originated in Mexico had a greater impact on the equity risk premium than the recent 2008 financial crisis. In particular, the conditional variance of excess return and production growth contributed to the equity risk premium a lot more than during any other period. All three components of the conditional variance reached a historic peak during the tequila crisis and were relatively stable during the 2008 financial crisis. This is very strong evidence on the importance of the origin of the contraction in a business cycle to be able to predict its impact on the Mexican stock market.

We found evidence of an asymmetric response of the equity risk premium and the three macroeconomic variables to a positive and negative demand and supply shock. A positive supply shock has a longer effect on inflation than a negative shock. The same is true for the equity risk premium, where a supply shock lasts for 12 months while a negative supply shock only lasts for 3 months. For production growth, a positive supply shock was found to not be significant and a negative supply shock was found to have a positive effect for one month. Neither supply or demand shocks were found to be significant for money growth.

On the demand side, we found that a negative demand shock has a stronger impact on inflation than a positive shock. Inflation response to a negative demand shock is negative, significant and lasts for a year. It was also found that the response of the equity risk premium to a positive demand shock is negative but not significant and its response to a negative demand shock is also negative, significant and lasts for a year. Production growth response to a positive demand shock is negative and its response to a negative demand shock is positive.

In sum, it was shown that for Mexico the business cycle has significant effects on the equity risk premium. The source of the recession plays an important role in determining the magnitude of transmission to the Mexican stock market.. Conditional correlations between excess return and macroeconomic factors are time-varying but do not show a pattern during recessions. The volatility of excess return and the three macroeconomic factors seem to only have behaved differently during the tequila crisis but otherwise do not show a significant difference between recessions and periods of expansion.

For future research, it would be interesting to investigate the recent tax reform on stock market returns in Mexico, by using the results presented here to predict the effect on excess returns. Alternatively, one could use our results to quantify the effect on the equity risk premium of a sudden reduction in the central bank's key interest rate.

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# 5 Appendices

## 5.1 Appendix 1. Tables

Table A1.1 Vector autoregression lag order selection.

VAR Lag Order Selection Criteria
Endogenous variables: RETURN INFLATION OUTPUT MONEY
Exogenous variables: C
Date: 05/31/14 Time: 00:30
Sample: 1993M02 2013M12
Included observations: 239

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| 0 | 837.4239 | NA | 1.10e-08 | -6.974259 | -6.916075 | -6.950812 |
| 1 | 1042.483 | 401.5374 | 2.26e-09 | -8.556340 | -8.265422* | -8.439108 |
| 2 | 1070.028 | 53.01649 | 2.05e-09 | -8.652955 | -8.129303 | -8.441938 |
| 3 | 1099.633 | 55.99001 | 1.83e-09 | -8.766807 | -8.010422 | -8.462005* |
| 4 | 1112.533 | 23.96480 | 1.88e-09 | -8.740865 | -7.751746 | -8.342277 |
| 5 | 1151.833 | 71.69320 | 1.55e-09 | -8.935842 | -7.713989 | -8.443469 |
| 6 | 1165.286 | 24.09113 | 1.58e-09 | -8.914526 | -7.459939 | -8.328368 |
| 7 | 1188.688 | 41.12551 | 1.49e-09 | -8.976471 | -7.289150 | -8.296527 |
| 8 | 1204.445 | 27.16207 | 1.50e-09 | -8.974434 | -7.054379 | -8.200705 |
| 9 | 1222.825 | 31.06988* | 1.47e-09* | -8.994354* | -6.841565 | -8.126840 |
| 10 | 1229.488 | 11.04016 | 1.60e-09 | -8.916221 | -6.530698 | -7.954921 |
| 11 | 1242.531 | 21.17376 | 1.65e-09 | -8.891473 | -6.273216 | -7.836388 |
| 12 | 1249.990 | 11.85914 | 1.78e-09 | -8.819999 | -5.969008 | -7.671128 |

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table A1.2 Seasonality test for the excess return.

Excess Return

F-tests for seasonality

Test for the presence of seasonality assuming stability.

| | Sum of Squares | Dgrs.of Freedom | Mean Square | F-Value |
|---|---|---|---|---|
| Between months | 1.8244 | 11 | 0.16586 | 1.315 |
| Residual | 30.1384 | 239 | 0.12610 | |
| Total | 31.9628 | 250 | | |

No evidence of stable seasonality at the 0.1 per cent level.

Nonparametric Test for the Presence of Seasonality Assuming Stability

| Kruskal-Wallis Statistic | Degrees of Freedom | Probability Level |
|---|---|---|
| 19.6233 | 11 | 5.078% |

No evidence of seasonality at the one percent level.

Table A1.3 Seasonality test for production growth.

OUTPUT

F-tests for seasonality

Test for the presence of seasonality assuming stability.

| | Sum of Squares | Dgrs.of Freedom | Mean Square | F-Value |
|---|---|---|---|---|
| Between months | 0.0430 | 11 | 0.00391 | 1.252 |
| Residual | 0.7462 | 239 | 0.00312 | |
| Total | 0.7892 | 250 | | |

No evidence of stable seasonality at the 0.1 per cent level.

Nonparametric Test for the Presence of Seasonality Assuming Stability

| Kruskal-Wallis Statistic | Degrees of Freedom | Probability Level |
|---|---|---|
| 5.4899 | 11 | 90.514% |

No evidence of seasonality at the one percent level.

Table A1.4 Seasonality test for the money growth.

```
F-tests for seasonality

Test for the presence of seasonality assuming stability.
```

| | Sum of Squares | Dgrs.of Freedom | Mean Square | F-Value |
|---|---|---|---|---|
| Between months | 12.0832 | 11 | 1.09847 | 146.197** |
| Residual | 1.7958 | 239 | 0.00751 | |
| Total | 13.8790 | 250 | | |

```
**Seasonality present at the 0.1 per cent level.

Nonparametric Test for the Presence of Seasonality Assuming Stability
```

| Kruskal-Wallis Statistic | Degrees of Freedom | Probability Level |
|---|---|---|
| 181.9357 | 11 | 0.000% |

```
Seasonality present at the one percent level.
```

Table A1.5 Seasonality test for inflation.

```
INFLATION

F-tests for seasonality

Test for the presence of seasonality assuming stability.
```

| | Sum of Squares | Dgrs.of Freedom | Mean Square | F-Value |
|---|---|---|---|---|
| Between months | 0.0033 | 11 | 0.00030 | 0.782 |
| Residual | 0.0909 | 239 | 0.00038 | |
| Total | 0.0941 | 250 | | |

```
No evidence of stable seasonality at the 0.1 per cent level.

Nonparametric Test for the Presence of Seasonality Assuming Stability
```

| Kruskal-Wallis Statistic | Degrees of Freedom | Probability Level |
|---|---|---|
| 6.9896 | 11 | 79.993% |

```
No evidence of seasonality at the one percent level.
```

Table A1.6 Seasonality test for inflation after X12-ARIMA.

F-tests for seasonality

Test for the presence of seasonality assuming stability.

| | Sum of Squares | Dgrs.of Freedom | Mean Square | F-Value |
|---|---|---|---|---|
| Between months | 12.0832 | 11 | 1.09847 | 146.197** |
| Residual | 1.7958 | 239 | 0.00751 | |
| Total | 13.8790 | 250 | | |

**Seasonality present at the 0.1 per cent level.

Nonparametric Test for the Presence of Seasonality Assuming Stability

| Kruskal-Wallis Statistic | Degrees of Freedom | Probability Level |
|---|---|---|
| 181.9357 | 11 | 0.000% |

Seasonality present at the one percent level.

Table A1.7 Seasonality test for money after X12-ARIMA.

MONEY

F-tests for seasonality

Test for the presence of seasonality assuming stability.

| | Sum of Squares | Dgrs.of Freedom | Mean Square | F-Value |
|---|---|---|---|---|
| Between months | 0.0295 | 11 | 0.00268 | 0.459 |
| Residual | 1.3964 | 239 | 0.00584 | |
| Total | 1.4260 | 250 | | |

No evidence of stable seasonality at the 0.1 per cent level.

Nonparametric Test for the Presence of Seasonality Assuming Stability

| Kruskal-Wallis Statistic | Degrees of Freedom | Probability Level |
|---|---|---|
| 1.6888 | 11 | 99.933% |

No evidence of seasonality at the one percent level.

Table A1.8 Cross-correlation of lagged excess return and inflation.

Sample: 1993M02 2013M12
Included observations: 251
Correlations are asymptotically consistent approximations

| RETURN,INFLATION(-i) | RETURN,INFLATION(+i) | i | lag | lead |
|---|---|---|---|---|
| | | 0 | 0.1594 | 0.1594 |
| | | 1 | 0.2245 | 0.1243 |
| | | 2 | 0.2671 | 0.0558 |
| | | 3 | 0.1728 | -0.0270 |
| | | 4 | 0.0786 | -0.0156 |
| | | 5 | 0.0496 | -0.0130 |
| | | 6 | 0.0462 | 0.0126 |
| | | 7 | 0.0400 | 0.0200 |
| | | 8 | 0.0963 | 0.0226 |
| | | 9 | 0.0489 | 0.0679 |
| | | 10 | 0.0577 | 0.0688 |
| | | 11 | 0.0349 | 0.0054 |
| | | 12 | -0.0110 | -0.0059 |

Table A1.9 Cross-correlation of lagged excess return and production.

Date: 06/01/14 Time: 16:11
Sample: 1993M02 2013M12
Included observations: 251
Correlations are asymptotically consistent approximations

| RETURN,OUTPUT(-i) | RETURN,OUTPUT(+i) | i | lag | lead |
|---|---|---|---|---|
| | | 0 | 0.0489 | 0.0489 |
| | | 1 | -0.0835 | 0.1139 |
| | | 2 | -0.1247 | 0.0782 |
| | | 3 | -0.0048 | 0.0549 |
| | | 4 | -0.1650 | -0.0174 |
| | | 5 | -0.1630 | 0.2299 |
| | | 6 | 0.0074 | 0.2104 |
| | | 7 | 0.0296 | 0.0880 |
| | | 8 | 0.0176 | -0.0215 |
| | | 9 | -0.1800 | 0.1942 |
| | | 10 | 0.0393 | -0.0019 |
| | | 11 | 0.0286 | -0.0654 |
| | | 12 | -0.0701 | 0.0493 |

Table A1.10 Cross-correlation of lagged money growth and inflation.

Sample: 1993M02 2013M12
Included observations: 251
Correlations are asymptotically consistent approximations

| INFLATION,MONEY(-i) | INFLATION,MONEY(+i) | i | lag | lead |
|---|---|---|---|---|
| | | 0 | 0.0638 | 0.0638 |
| | | 1 | -0.0562 | 0.1074 |
| | | 2 | -0.0551 | 0.1777 |
| | | 3 | -0.0703 | 0.2756 |
| | | 4 | -0.0712 | 0.2740 |
| | | 5 | 0.0067 | 0.3239 |
| | | 6 | 0.0099 | 0.3313 |
| | | 7 | 0.0042 | 0.3089 |
| | | 8 | -0.0048 | 0.3560 |
| | | 9 | -0.0211 | 0.3601 |
| | | 10 | -0.0531 | 0.3564 |
| | | 11 | -0.0424 | 0.4152 |
| | | 12 | -0.0361 | 0.3556 |

Table A1.11 Cross-correlation of lagged money growth and production.

Sample: 1993M02 2013M12
Included observations: 251
Correlations are asymptotically consistent approximations

| OUTPUT,MONEY(-i) | OUTPUT,MONEY(+i) | i | lag | lead |
|---|---|---|---|---|
| | | 0 | 0.2079 | 0.2079 |
| | | 1 | 0.1733 | 0.1467 |
| | | 2 | 0.2256 | 0.1423 |
| | | 3 | 0.1011 | 0.1768 |
| | | 4 | 0.1361 | 0.0950 |
| | | 5 | 0.0889 | 0.0337 |
| | | 6 | 0.0735 | 0.0279 |
| | | 7 | 0.1277 | -0.0082 |
| | | 8 | 0.0281 | -0.0517 |
| | | 9 | -0.0101 | -0.0244 |
| | | 10 | 0.0766 | 0.0248 |
| | | 11 | -0.0895 | -0.1204 |
| | | 12 | -0.0140 | 0.0308 |

Table A1.12 Test for ARCH effects on excess return.

Heteroskedasticity Test: ARCH

| | | | |
|---|---|---|---|
| F-statistic | 0.475489 | Prob. F(12,220) | 0.9277 |
| Obs*R-squared | 5.890267 | Prob. Chi-Square(12) | 0.9215 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/01/14 Time: 19:22
Sample (adjusted): 1994M08 2013M12
Included observations: 233 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.115463 | 0.041710 | 2.768255 | 0.0061 |
| RESID^2(-1) | 0.129369 | 0.067417 | 1.918955 | 0.0563 |
| RESID^2(-2) | -0.014518 | 0.067968 | -0.213604 | 0.8311 |
| RESID^2(-3) | -0.013229 | 0.067967 | -0.194632 | 0.8459 |
| RESID^2(-4) | 0.061681 | 0.067861 | 0.908944 | 0.3644 |
| RESID^2(-5) | 0.018168 | 0.067967 | 0.267302 | 0.7895 |
| RESID^2(-6) | 0.026813 | 0.067939 | 0.394659 | 0.6935 |
| RESID^2(-7) | 0.032326 | 0.067914 | 0.475979 | 0.6346 |
| RESID^2(-8) | -0.023594 | 0.067418 | -0.349960 | 0.7267 |
| RESID^2(-9) | -0.034481 | 0.067308 | -0.512287 | 0.6090 |
| RESID^2(-10) | 0.004161 | 0.067352 | 0.061773 | 0.9508 |
| RESID^2(-11) | 0.004423 | 0.067209 | 0.065809 | 0.9476 |
| RESID^2(-12) | 0.011634 | 0.066674 | 0.174491 | 0.8616 |

| | | | |
|---|---|---|---|
| R-squared | 0.025280 | Mean dependent var | 0.145162 |
| Adjusted R-squared | -0.027886 | S.D. dependent var | 0.441106 |
| S.E. of regression | 0.447214 | Akaike info criterion | 1.282619 |
| Sum squared resid | 44.00011 | Schwarz criterion | 1.475166 |
| Log likelihood | -136.4251 | Hannan-Quinn criter. | 1.360262 |
| F-statistic | 0.475489 | Durbin-Watson stat | 2.000574 |
| Prob(F-statistic) | 0.927683 | | |

Table A1.13 Test for ARCH effects on inflation.

Heteroskedasticity Test: ARCH

| | | | |
|---|---|---|---|
| F-statistic | 24.89686 | Prob. F(12,226) | 0.0000 |
| Obs*R-squared | 136.0696 | Prob. Chi-Square(12) | 0.0000 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/01/14 Time: 20:04
Sample (adjusted): 1994M02 2013M12
Included observations: 239 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.63E-35 | 1.52E-35 | 1.074686 | 0.2837 |
| RESID^2(-1) | 0.808589 | 0.065600 | 12.32605 | 0.0000 |
| RESID^2(-2) | -0.261491 | 0.084119 | -3.108605 | 0.0021 |
| RESID^2(-3) | 0.299941 | 0.085869 | 3.493015 | 0.0006 |
| RESID^2(-4) | -0.228348 | 0.088154 | -2.590342 | 0.0102 |
| RESID^2(-5) | 0.184667 | 0.089310 | 2.067701 | 0.0398 |
| RESID^2(-6) | -0.073591 | 0.090128 | -0.816513 | 0.4151 |
| RESID^2(-7) | 0.035392 | 0.090130 | 0.392684 | 0.6949 |
| RESID^2(-8) | 0.077840 | 0.089318 | 0.871491 | 0.3844 |
| RESID^2(-9) | -0.012648 | 0.088168 | -0.143449 | 0.8861 |
| RESID^2(-10) | -0.033838 | 0.085882 | -0.394001 | 0.6940 |
| RESID^2(-11) | -0.164761 | 0.084130 | -1.958416 | 0.0514 |
| RESID^2(-12) | 0.165626 | 0.065601 | 2.524766 | 0.0123 |

| | | | |
|---|---|---|---|
| R-squared | 0.569329 | Mean dependent var | 8.12E-35 |
| Adjusted R-squared | 0.546461 | S.D. dependent var | 3.26E-34 |
| S.E. of regression | 2.19E-34 | Sum squared resid | 1.09E-65 |
| F-statistic | 24.89686 | Durbin-Watson stat | 1.954715 |
| Prob(F-statistic) | 0.000000 | | |

Table A1.14 Test for ARCH effects on production.

Heteroskedasticity Test: ARCH

| | | | |
|---|---|---|---|
| F-statistic | 15.29178 | Prob. F(12,225) | 0.0000 |
| Obs*R-squared | 106.9111 | Prob. Chi-Square(12) | 0.0000 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/01/14 Time: 20:06
Sample (adjusted): 1994M03 2013M12
Included observations: 238 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.001459 | 0.000861 | 1.694793 | 0.0915 |
| RESID^2(-1) | 0.766524 | 0.066089 | 11.59827 | 0.0000 |
| RESID^2(-2) | -0.294788 | 0.083172 | -3.544308 | 0.0005 |
| RESID^2(-3) | -0.004283 | 0.085367 | -0.050172 | 0.9600 |
| RESID^2(-4) | 0.055747 | 0.084514 | 0.659626 | 0.5102 |
| RESID^2(-5) | -0.088263 | 0.084415 | -1.045581 | 0.2969 |
| RESID^2(-6) | 0.104366 | 0.084139 | 1.240399 | 0.2161 |
| RESID^2(-7) | -0.133877 | 0.084129 | -1.591326 | 0.1129 |
| RESID^2(-8) | 0.084538 | 0.084361 | 1.002106 | 0.3174 |
| RESID^2(-9) | 0.181583 | 0.084412 | 2.151142 | 0.0325 |
| RESID^2(-10) | -0.062699 | 0.085255 | -0.735422 | 0.4628 |
| RESID^2(-11) | -0.117108 | 0.083079 | -1.409596 | 0.1600 |
| RESID^2(-12) | 0.131075 | 0.066049 | 1.984515 | 0.0484 |

| | | | |
|---|---|---|---|
| R-squared | 0.449206 | Mean dependent var | 0.003875 |
| Adjusted R-squared | 0.419831 | S.D. dependent var | 0.014948 |
| S.E. of regression | 0.011385 | Akaike info criterion | -6.059903 |
| Sum squared resid | 0.029166 | Schwarz criterion | -5.870241 |
| Log likelihood | 734.1284 | Hannan-Quinn criter. | -5.983466 |
| F-statistic | 15.29178 | Durbin-Watson stat | 1.978607 |
| Prob(F-statistic) | 0.000000 | | |

Table A1.14 Test for ARCH effects on money.

Heteroskedasticity Test: ARCH

| | | | |
|---|---|---|---|
| F-statistic | 1.402839 | Prob. F(12,221) | 0.1658 |
| Obs*R-squared | 16.56268 | Prob. Chi-Square(12) | 0.1668 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 06/01/14 Time: 20:07
Sample (adjusted): 1994M07 2013M12
Included observations: 234 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.005009 | 0.001843 | 2.718141 | 0.0071 |
| RESID^2(-1) | 0.104648 | 0.067301 | 1.554937 | 0.1214 |
| RESID^2(-2) | 0.080607 | 0.067833 | 1.188313 | 0.2360 |
| RESID^2(-3) | 0.179442 | 0.067726 | 2.649546 | 0.0086 |
| RESID^2(-4) | -0.076004 | 0.068742 | -1.105634 | 0.2701 |
| RESID^2(-5) | -0.053220 | 0.068889 | -0.772558 | 0.4406 |
| RESID^2(-6) | 0.059297 | 0.068962 | 0.859852 | 0.3908 |
| RESID^2(-7) | 0.024943 | 0.068964 | 0.361685 | 0.7179 |
| RESID^2(-8) | 0.029062 | 0.068900 | 0.421800 | 0.6736 |
| RESID^2(-9) | 0.047048 | 0.068738 | 0.684462 | 0.4944 |
| RESID^2(-10) | -0.009237 | 0.067723 | -0.136400 | 0.8916 |
| RESID^2(-11) | -0.001561 | 0.067520 | -0.023126 | 0.9816 |
| RESID^2(-12) | 0.001949 | 0.067190 | 0.029015 | 0.9769 |

| | | | |
|---|---|---|---|
| R-squared | 0.070781 | Mean dependent var | 0.008161 |
| Adjusted R-squared | 0.020325 | S.D. dependent var | 0.019081 |
| S.E. of regression | 0.018886 | Akaike info criterion | -5.046821 |
| Sum squared resid | 0.078828 | Schwarz criterion | -4.854859 |
| Log likelihood | 603.4780 | Hannan-Quinn criter. | -4.969422 |
| F-statistic | 1.402839 | Durbin-Watson stat | 1.997955 |
| Prob(F-statistic) | 0.165819 | | |

Table A1.15 Vector autoregression for risk premium and macroeconomic variables.

Vector Autoregression Estimates
Date: 06/03/14 Time: 05:25
Sample (adjusted): 1993M06 2013M12
Included observations: 247 after adjustments
Standard errors in ( ) & t-statistics in [ ]

| | RP2 | INFLATION | OUTPUT | MONEY |
|---|---|---|---|---|
| RP2(-1) | 0.703985 | -0.133405 | -0.022572 | -0.054740 |
| | (0.05731) | (0.03263) | (0.08761) | (0.11853) |
| | [ 12.2833] | [-4.08799] | [-0.25764] | [-0.46184] |
| RP2(-2) | 0.442435 | 0.090831 | -0.163933 | 0.040064 |
| | (0.06617) | (0.03768) | (0.10116) | (0.13685) |
| | [ 6.68601] | [ 2.41067] | [-1.62056] | [ 0.29275] |
| RP2(-3) | -0.387696 | 0.034228 | 0.222014 | 0.039399 |
| | (0.05010) | (0.02853) | (0.07659) | (0.10361) |
| | [-7.73842] | [ 1.19984] | [ 2.89884] | [ 0.38026] |
| INFLATION(-1) | 0.392545 | 0.917973 | -0.475277 | -0.180869 |
| | (0.11426) | (0.06506) | (0.17466) | (0.23629) |
| | [ 3.43566] | [ 14.1103] | [-2.72114] | [-0.76545] |
| INFLATION(-2) | 0.657945 | -0.021162 | 0.522972 | 0.065120 |
| | (0.15312) | (0.08719) | (0.23408) | (0.31667) |
| | [ 4.29682] | [-0.24272] | [ 2.23418] | [ 0.20564] |
| INFLATION(-3) | -0.465412 | 0.054353 | -0.031125 | 0.532618 |
| | (0.12927) | (0.07361) | (0.19762) | (0.26735) |
| | [-3.60019] | [ 0.73842] | [-0.15750] | [ 1.99221] |
| OUTPUT(-1) | 0.008784 | -0.065494 | -0.092300 | 0.048946 |
| | (0.04282) | (0.02438) | (0.06545) | (0.08855) |
| | [ 0.20515] | [-2.68634] | [-1.41014] | [ 0.55275] |
| OUTPUT(-2) | -0.030028 | -0.033770 | -0.128406 | 0.073874 |
| | (0.04275) | (0.02434) | (0.06535) | (0.08840) |
| | [-0.70247] | [-1.38744] | [-1.96502] | [ 0.83565] |
| OUTPUT(-3) | -0.080935 | 0.014241 | -0.044969 | 0.131404 |
| | (0.04220) | (0.02403) | (0.06451) | (0.08728) |
| | [-1.91779] | [ 0.59265] | [-0.69705] | [ 1.50558] |
| MONEY(-1) | 0.099858 | -0.065887 | 0.082417 | -0.092310 |
| | (0.02966) | (0.01689) | (0.04534) | (0.06134) |
| | [ 3.36663] | [-3.90122] | [ 1.81765] | [-1.50485] |
| MONEY(-2) | -0.062700 | 0.013001 | 0.116230 | 0.141350 |
| | (0.03036) | (0.01729) | (0.04641) | (0.06278) |
| | [-2.06544] | [ 0.75217] | [ 2.50464] | [ 2.25150] |
| MONEY(-3) | -0.036324 | -0.009175 | 0.061239 | 0.325434 |
| | (0.03088) | (0.01758) | (0.04720) | (0.06385) |
| | [-1.17644] | [-0.52189] | [ 1.29744] | [ 5.09648] |
| C | 0.007818 | 0.009223 | -0.014618 | 0.029605 |
| | (0.00492) | (0.00280) | (0.00752) | (0.01017) |
| | [ 1.59019] | [ 3.29497] | [-1.94509] | [ 2.91185] |
| R-squared | 0.922080 | 0.813888 | 0.139403 | 0.269675 |
| Adj. R-squared | 0.918084 | 0.804343 | 0.095270 | 0.232223 |
| Sum sq. resids | 0.345122 | 0.111892 | 0.806504 | 1.476083 |
| S.E. equation | 0.038404 | 0.021867 | 0.058708 | 0.079423 |
| F-statistic | 230.7558 | 85.27545 | 3.158681 | 7.200457 |
| Log likelihood | 461.3181 | 600.4234 | 356.4898 | 281.8418 |
| Akaike AIC | -3.630106 | -4.756465 | -2.781294 | -2.176856 |
| Schwarz SC | -3.445402 | -4.571760 | -2.596589 | -1.992152 |
| Mean dependent | 0.128277 | 0.040897 | 0.009949 | 0.084015 |
| S.D. dependent | 0.134182 | 0.049436 | 0.061721 | 0.090642 |

| | |
|---|---|
| Determinant resid covariance (dof adj.) | 1.48E-11 |
| Determinant resid covariance | 1.19E-11 |
| Log likelihood | 1704.774 |
| Akaike information criterion | -13.38279 |
| Schwarz criterion | -12.64397 |

Table A1.16 Firms used in the sample.

Arca Continental, S. A. B. de C. V.
Accel SAB de CV
Corporación Actinver S.A.B. de C.V.
Grupo Aeromexico SAB de CV
Alfa S.A.B de C.V
ALPEK, S.A.B. de C.V.
Alsea, S.A.B. De C.V.
America Movil S.A.B. de C.V.
Consorcio ARA, S. A. B. de C. V.
Grupo Aeroportuario del Sureste, SAB de CV
Compañía Minera Autlán S.A.B. of C.V.
Axtel S. A.. B. De CV
TV Azteca SAB de CV
Industrias Bachoco S.A.B. de C.V.
Grupo Bafar S.A.B. de C.V.
Farmacias Benavides, S.A.B. de C.V.
Grupo Bimbo, S.A.B. de C.V.
Bolsa Mexicana de Valores SAB de CV
Empresas Cablevisión, S.A.B. de C.V.
CEMEX, S.A.B. de C.V.
Internacional de Cerámica, S.A.B. de C.V.
Grupo Comercial Chedraui, S.A.B. DE C.V.
Grupe, S.A.B. de C.V.
Corporación Interamericana de Entretenimiento, SAB de CV
Corporación Moctezuma, SAB de CV
Corporación Mexicana De Restaurantes S.A.B. De C.V.
Controladora Comercial Mexicana SAB DE CV
Crédito Real, S.A.B. de C.V., Sociedad Financiera De Objeto Múltiple, Entidad No Regulada
Organización Cultiba, S.A.B. de C.V.
Cydsa SAB de CV
Edoardos Martin S.A.B. de C.V.Grupo Elektra, S.A.B. de C.V.
Fomento Económico Mexicano, S.A.B de C.V
Casa de Bolsa Finamex Sociedad Anónima Bursátil de Capital Variable
Corporativo Fragua, S.A.B. De C.V.
Fibra UNO
Grupo Aeroportuario del Pacifico S.A.B. de CV
Corporativo GBM SAB de CV
Grupo Carso, S.A.B. de C.V.
Grupo Cementos de Chihuahua SAB de CV
General de Seguros, S.A.B.
Gentera S.A.B. de C.V.
Grupo Famsa S.A.B. de C.V.
Grupo Financiero Inbursa, S.A.B. de C.V.
Grupo Financiero Interacciones SA de CV

Grupo Financiero Multiva, S.A.B. de C.V.
Grupo Financiero Banorte, S.A.B. de C.V.
Banregio Grupo Financiero, S.A.B de C.V.
Grupo Gigante SAB de CV
Grupo Industrial Saltillo, SAB de CV
Grupo Mexicano de Desarrollo SA
Gmd Resorts SAB
Grupo México S.A.B. de C.V.
Grupo Modelo, S.A.B. de C.V.
Grupo Nacional Provincial, S. A. B.
Grupo Palacio de Hierro SAB de CV
Grupo Profuturo, S.A.B. de C.V.
Gruma S.A.B. de CV
Grupo Sanborns, S.A.B. de C.V.
Grupo Herdez,Sociedad Anónima Bursátil de Capital Variable
Hilasal Mexicana, S.A.B. de C.V.
Consorcio Hogar, S.A.B. de C.V.
Desarrolladora Homex, SAB de CV
Empresas ICA, S.A.B. de C.V.
Industrias CH, SAB de CV
Impulsora del Desarrollo y el Empleo en América Latina, S.A.B. de C.V.
Infraestructura Energética Nova, S.A.B. de C.V.
Inmuebles Carso, S.A.B. de C.V.
INVEX Controladora, S.A.B. de C.V.
Kimberly-Clark de México, SAB de CV
Coca-Cola FEMSA S.A.B de C.V.
Grupo Kuo, S.A.B. de C.V.
Genomma Lab Internacional SAB de CV
Grupo Lala, S.A.B. de C.V.
Grupo Lamosa, SAB de CV
El Puerto de Liverpool, SAB de CV
Peña Verde, S.A.B.
Quálitas Controladora, S.A.B. de C.V.
Grupo Radio Centro, S.A.B. de C.V.
SANLUIS Corporacion SAB de CV
Grupo Financiero Santander Mexico, S.A.B. de C.V.
Sare Holding SAB de CV
Grupo Sports World, S.A.B. de C.V.
Proteak Uno, S.A.P.I.B. De C.V.
Grupo Televisa, S.A.B.
Grupo TMM S.A.B.
Value Grupo Financiero SAB de CV
Grupo Vasconia, S.A.B.
Corporación Inmobiliaria Vesta, S.A.B. de C.V.
Vitro, S.A.B. de C.V.
Wal-Mart de Mexico SAB De CV

## 5.2 Appendix 2. Restrictive model

I also estimated a restricte version of four variable BEKK of Engle and Kroner (1995):

$$Y_t = \mu + \lambda * H_t + \epsilon_t$$

where $\mu$ is a $Nx1$ vector of constant terms, $\lambda$ is a $Nx1$ parameter vector, $H$ is a $NxN$ variance-covariance matrix and $\epsilon$ is the error term. I used the same four variables for vector $Y$: excess return, inflation, production and money.

$$\epsilon \sim N(0, H)$$

$$H_{t+1} = \Omega\Omega' + \beta H_t \beta' + \alpha \epsilon_t \epsilon_t' \alpha$$

$$\lambda = \begin{bmatrix} 0.716124 \\ (2112266) \\ 1.463283 \\ (2.65e+12) \\ 5.480712 \\ (6.81E+32) \\ 0.939113 \\ (200176) \end{bmatrix}$$

$$
\Omega = \begin{bmatrix}
0.037453 & 0 & 0 & 0 \\
(0.406) & & & \\
-0.002031 & 0.002460 & 0 & 0 \\
(0.030) & (0.059) & & \\
0.002469 & -0.000666 & 0.026341 & 0 \\
(0.027) & (0.054) & (0.011) & \\
0.002007 & 0.002807 & -0.033188 & 0.112358 \\
(0.025) & (0.041) & (-0.091) & (1.251)
\end{bmatrix}
$$

$$
\beta = \begin{bmatrix}
0.103967 & 0 & 0 & 0 \\
(9.013) & & & \\
0 & 0.091357 & 0 & 0 \\
 & (9.780) & & \\
0 & 0 & 0.076536 & 0 \\
 & & (8.607) & \\
0 & 0 & 0 & 0.086865 \\
 & & & (11.168)
\end{bmatrix}
$$

$$
\alpha = \begin{bmatrix}
0.354350 & 0 & 0 & 0 \\
(5.853) & & & \\
0 & 0.360012 & 0 & 0 \\
 & (3.569) & & \\
0 & 0 & 0.627875 & 0 \\
 & & (4.293) & \\
0 & 0 & 0 & 0.106469 \\
 & & & (0.22)
\end{bmatrix}
$$

Log likelihood 21.59502

## 5.3 Appendix 3. Codes

### 5.3.1 Matlab code

For estimation of BEKK model, I used Kevin Sheppard's MFET toolbox which is availabe on his webpage: www.kevinsheppard.com.

Code for the maximum likelihood estimation of equation (10): load matrix.mat

```
%Initial values from univariate estimation and VAR
P1 = [ 0.00918; 0.007933; 0.086104];
P11 = [ 0.0016; 0.647499; 0.0193; -0.0107; 0.0142; 0.0535; -0.130761
;-0.0062; 0.0009;-0.2150; 0.0475; -0.190840];
Theta = [ 0.106455; 1.19; 0.5; -0.17];
P0 = [B1; B11; Theta];

%estimation
L =@(B) ML_Garch_M(P,Yt,Yt_1,Ht); options =
optimset('MaxFunEvals',1000*size(B0,1),'MaxIter',1000*size(B0,1),
'TolFun',1e-10,'TolX',1e-10,'LargeScale','Off','Display','Off');

[params llk xx yy grad hessian] = fminunc(L, P0, options);

stderros = inv(hessian);
l = -llk

function [MLGARCHM] = ML_Garch_M(P,Yt,Yt_1,Ht)

[T,N] = size(Yt_1);
start = ones(T,N);

et1 = Yt(1,1) - ([B(16), B(17), B(18), B(19)])*(Ht(:,1,1))
et2 = Yt(1,2) - P(1) - ([P(4), P(5), P(6), P(7)])*Yt_1(1,:)'
et3 = Yt(1,3) - P(2) - ([P(8), P(9), P(10), P(11)])*Yt_1(1,:)'
```

```
et4 = Yt(1,4) - P(3) - ([P(12), P(13), P(14), P(15)])*Yt_1(1,:)'

LLK = 0;

for t = 2:T

et1 = Yt(t,1) - ([P(16), P(17), P(18), P(19)])*(Ht(:,1,t))

et2 = Yt(t,2) - P(1) - ([P(4), P(5), P(6), P(7)])*Yt_1(t,:)'

et3 = Yt(t,3) - P(2) - ([P(8), P(9), P(10), P(11)])*Yt_1(t,:)'

et4 = Yt(1,4) - B(3) - ([P(12), P(13), P(14), P(15)])*Yt_1(t,:)'

et = [et1; et2; et3; et4];

llkt = - (N/2)*log(2*pi) - (1/2)*log(max(1e-30,det(Ht(:,:,t))))- (1/2)*(et'*inv(Ht(:,:,t))*et);

llkt = -llkt; LLK = LLK + llkt; end

MLGARCHM = LLK;
```

### 5.3.2 E-views code for the restrictive model

```
' restricted version of four variable BEKK of Engle and Kroner (1995): '

' y = mu + lambda*H + res ' res ~ N(0,H)

' H = omega*omega' + beta H(-1) beta' + alpha res(-1) res(-1)' alpha'

' where, ' y = 3 x 1 ' H = 3 x 3 ' H(1,1) = variance of y1

' H(1,2) = cov of y1 and y2 ' H(1,3) = cov of y1 and y2

' H(2,2) = variance of y2 ' H(2,3) = cov of y1 and y3

' H(3,3) = variance of y3 ' omega = 3 x 3 low triangular

' beta = 3 x 3 diagonal ' alpha = 3 x 3 diagonal '

' load workfile

load base_completa1.wf1

' dependent variables

series y1 = return

series y2 = inflation
```

```
series y3 = production
series y4 = money
' set sample
sample s0 1993m02 2015m12 sample s1 1993m03 2013m12
' initialization of parameters
smpl s0
' starting values from univariate GARCH
equation eq1.arch(archm=var,m=100,c=1e-5) y1
equation eq2.arch(archm=std,m=100,c=1e-5) y2
equation eq3.arch(archm=var,m=100,c=1e-5) y3
equation eq4.arch(archm=std,m=100,c=1e-5) y4
'conditional variances
eq1.makegarch garch1
eq2.makegarch garch2
eq3.makegarch garch3
eq4.makegarch garch4
' declare coef vectors to use in GARCH model
coef(4) lambda
lambda(1) = eq1.c(1)
lambda(2) = eq2.c(1)
lambda(3) = eq3.c(1)
lambda(4) = eq4.c(1)
coef(10) omega
omega(1) = (eq1.c(2))^.5
omega(2) = 0
omega(3) = 0
omega(4) = 0
```

```
omega(5) = (eq2.c(2))^.5
omega(6) = 0
omega(7) = 0
omega(8) = (eq3.c(2))^.5
omega(9) = 0
omega(10) = (eq4.c(2))^.5
coef(4) alpha
alpha(1) = (eq1.c(3))^.5
alpha(2) = (eq2.c(3))^.5
alpha(3) = (eq3.c(3))^.5
alpha(4) = (eq4.c(3))^.5
coef(4) beta
beta(1) = (eq1.c(4))^.5
beta(2) = (eq2.c(4))^.5
beta(3) = (eq3.c(4))^.5
beta(4) = (-eq4.c(4))^.5

' use sample var-cov as starting value of variance-covariance matrix
series cov_y1y2 = @cov(y1-lambda(1)*garch1, y2-lambda(2)*garch2)
series cov_y1y3 = @cov(y1-lambda(1)*garch1, y3-lambda(3)*garch3)
series cov_y1y4 = @cov(y1-lambda(1)*garch1, y4-lambda(4)*garch4)
series cov_y2y3 = @cov(y2-lambda(2)*garch2, y3-lambda(3)*garch3)
series cov_y2y4 = @cov(y2-lambda(4)*garch2, y4-lambda(4)*garch4)
series cov_y3y4 = @cov(y3-lambda(4)*garch3, y4-lambda(4)*garch4)
series var_y1 = @var(y1-lambda(1)*garch1)
series var_y2 = @var(y2-lambda(2)*garch2)
series var_y3 = @var(y3-lambda(3)*garch3)
series var_y4= @var(y4-lambda(4)*garch4)
series sqres1 = (y1-lambda(1)*garch1)^2
```

series sqres2 = (y2-lambda(2)*garch2)^2

series sqres3 = (y3-lambda(3)*garch3)^2

series sqres4 = (y4-lambda(4)*garch4)^2

series res1res2 = (y1-lambda(1)*garch1)*(y2-lambda(2)*garch2)

series res1res3 = (y1-lambda(1)*garch1)*(y3-lambda(3)*garch3)

series res1res4 = (y1-lambda(1)*garch1)*(y4-lambda(4)*garch4)

series res2res3 = (y2-lambda(2)*garch2)*(y3-lambda(3)*garch3)

series res2res4 = (y2-lambda(2)*garch2)*(y4-lambda(4)*garch4)

series res3res4= (y3-lambda(3)*garch3)*(y4-lambda(4)*garch4)

' constant adjustment for log likelihood !mlog2pi = 3*log(2*@acos(-1))

' ........................................................... ' LOG LIKELIHOOD " .......................

logl cvgarchm

' squared errors and cross errors cvgarchm.append @logl logl cvgarchm.append

sqres1 = (y1-lambda(1)*var_y1)^2 cvgarchm.append

sqres2 = (y2-lambda(2)*var_y2)^2 cvgarchm.append

sqres3 = (y3-lambda(3)*var_y3)^2 cvgarchm.append

sqres4 = (y4-lambda(4)*var_y4)^2

cvgarchm.append res1res2 = (y1-lambda(1)*var_y1)*(y2-lambda(2)*var_y2)

cvgarchm.append res1res3 = (y1-lambda(1)*var_y1)*(y3-lambda(3)*var_y3)

cgarchm.append res1res4 = (y1-lambda(1)*var_y1)*(y4-lambda(4)*var_y4)

cvgarchm.append res2res3 = (y2-lambda(2)*var_y2)*(y3-lambda(3)*var_y3)

cvgarchm.append res2res4 = (y2-lambda(2)*var_y2)*(y4-lambda(4)*var_y4)

cvgarchm.append res3res4 = (y3-lambda(3)*var_y3)*(y4-lambda(4)*var_y4)

' variance and covariance series

cvgarchm.append var_y1 = omega(1)^2 + beta(1)^2*var_y1(-1)

+ alpha(1)^2*sqres1(-1)

cvgarchm.append var_y2 = omega(2)^2+omega(5)^2 + beta(2)^2*var_y2(-1)

```
+ alpha(2)^2*sqres2(-1)
cvgarchm.append var_y3 = omega(3)^2+omega(6)^2+omega(8)^2
+ beta(3)^2*var_y3(-1) + alpha(3)^2*sqres3(-1)
cvgarchm.append var_y4 = omega(4)^2+omega(7)^2+omega(9)^2 +omega(10)^2
+ beta(4)^2*var_y4(-1) + alpha(4)^2*sqres4(-1)
cvgarchm.append cov_y1y2 = omega(1)*omega(2) + beta(2)*beta(1)*cov_y1y2(-1)
+ alpha(2)*alpha(1)*res1res2(-1)
cvgarchm.append cov_y1y3 = omega(1)*omega(3) + beta(3)*beta(1)*cov_y1y3(-1)
+ alpha(3)*alpha(1)*res1res3(-1)
cvgarchm.append cov_y1y4 = omega(1)*omega(4) + beta(4)*beta(1)*cov_y1y4(-1)
+ alpha(4)*alpha(1)*res1res4(-1)
cvgarchm.append cov_y2y3 = omega(2)*omega(3)
+ omega(5)*omega(6) + beta(3)*beta(2)*cov_y2y3(-1) + alpha(3)*alpha(2)*res2res3
cvgarchm.append cov_y2y4 = omega(3)*omega(4) + omega(6)*omega(7)
+ omega(8)*omega(9)+ beta(4)*beta(3)*cov_y3y4(-1) + alpha(4)*alpha(3)*res3res4

' determinant of the variance-covariance matrix
cvgarchm.append deth =
var_y1*var_y2*var_y3*var_y4
-var_y1*var_y2*cov_y3y4^2-var_y1*cov_y2y3^2*var_y4
+2*(var_y1*cov_y2y4*cov_y2y3*cov_y3y4)-var_y1*cov_y2y4^2*var_y3
-var_y3*var_y4*cov_y1y2^2
-cov_y3y4^2*cov_y1y2^2+var_y4*cov_y2y3*cov_y1y2*cov_y1y3
-cov_y1y4*cov_y2y3*cov_y3y4*cov_y1y2
-cov_y1y2*cov_y2y4*cov_y1y3*cov_y3y4+cov_y1y2*cov_y2y4*cov_y1y4*var_y3
+cov_y1y2*cov_y2y4*cov_y1y4*var_y3+cov_y1y3*cov_y1y2*cov_y2y3*var_y4^2
-cov_y1y3*cov_y1y2*cov_y3y4*cov_y2y4+cov_y1y3^2*var_y2*var_y4
-cov_y1y4*cov_y3y4*var_y2*cov_y1y3+cov_y1y3^2*cov_y2y4^2
-cov_y1y3*cov_y2y4*cov_y2y3*cov_y1y4
```

```
-cov_y1y4*cov_y1y2*cov_y2y3*cov_y3y4
+cov_y1y4*cov_y1y2*var_y3*cov_y2y4+cov_y1y4*var_y2*cov_y1y3*cov_y3y4
-cov_y1y4^2*var_y2*var_y3-cov_y1y4*cov_y2y3*cov_y1y3*cov_y2y4
+cov_y1y4^2*cov_y2y3^2

' calculate the elements of the inverse of var_cov (H) matrix
cvgarchm.append invh1 = (var_y2*var_y3*var_y4
- var_y2*cov_y3y4^2+cov_y2y3^2*var_y4-2*(cov_y2y4*cov_y2y3*cov_y3y4)
+cov_y2y4^2*var_y3)/deth
cvgarchm.append invh2 =
(var_y3*var_y4*cov_y1y2
-cov_y3y4^2*cov_y1y2-var_y4*cov_y2y3*cov_y1y3
+cov_y1y4*cov_y2y3*cov_y3y4+cov_y2y4*cov_y1y3*cov_y3y4
-cov_y2y4*cov_y1y4^2*var_y3)/deth
cvgarchm.append invh3 =(cov_y1y2*cov_y2y3*var_y4
-cov_y1y2*cov_y3y4*cov_y2y4-cov_y1y3*var_y2*var_y4
+cov_y1y4*cov_y3y4*var_y2+cov_y1y3*cov_y2y4^2
-cov_y2y4*cov_y2y3*cov_y1y4)/deth
cvgarchm.append invh4 =
(cov_y1y2*cov_y2y3*cov_y3y4-cov_y1y2*var_y3*cov_y2y4
+var_y2*cov_y1y3*cov_y3y4+cov_y1y4*var_y2*var_y3
+cov_y2y3*cov_y1y3*cov_y2y4-cov_y1y4*cov_y2y3^2)/deth
cvgarchm.append invh5 =(-var_y1*var_y3*var_y4 + var_y1*cov_y3y4^2
+cov_y1y3^2*var_y4-2*(cov_y1y4*cov_y1y3*cov_y3y4)
+cov_y1y4^2*var_y3)/deth
cvgarchm.append invh6 =(-var_y1*var_y4*cov_y2y3
+cov_y3y4*cov_y1y2*var_y1+var_y4*cov_y1y3*cov_y1y2
-cov_y1y4*cov_y1y3*cov_y2y4
-cov_y1y4*cov_y1y2*cov_y3y4+cov_y2y3*cov_y1y4^2)/deth
```

```
cvgarchm.append invh7 =(var_y1*cov_y2y3*cov_y3y4
+cov_y2y4*var_y3*var_y1+cov_y1y2*cov_y1y3*cov_y3y4
-cov_y1y3^2*cov_y2y4-cov_y1y4*cov_y1y2*var_y3
+cov_y1y4*cov_y2y3*cov_y1y3)/deth
cvgarchm.append invh8 =(var_y1*var_y2*var_y4-var_y1*cov_y2y4^2
-cov_y1y2^2*var_y4+2*(cov_y1y4*cov_y2y4*cov_y1y2)
-cov_y1y4^2*var_y2)/deth
cvgarchm.append invh9 =(var_y1*var_y2*cov_y3y4
-var_y1*cov_y2y4*cov_y2y3
-cov_y1y2^2*cov_y3y4+2*(cov_y1y3*cov_y2y4*cov_y1y2)
-cov_y1y4*var_y2*cov_y1y3)/deth
cvgarchm.append invh10 =
(-var_y1*var_y2*var_y3-var_y1*cov_y2y3^2
-cov_y1y2^2*var_y3-2*(cov_y1y3*cov_y2y3*cov_y1y2)
+cov_y1y3^2*var_y2)/deth

' log-likelihood series cvgarchm.append logl = -0.5*(!mlog2pi
+ (invh1*sqres1+invh5*sqres2+invh8*sqres3+invh10*sqres4
+2*invh2*res1res2 +2*invh3*res1res3+2*invh4*res1res4
+2*invh6*res2res3+2*invh7*res2res4+2*invh9*res3res4 ) + log(deth))

' estimate the model
smpl s1 cvgarchm.ml(showopts, m=100, c=1e-5)
```