The Role of Money in Economies with Monetary Policy Regimes that Ignore Monetary Aggregates

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The role of money in economies with monetary policy regimes that ignore monetary aggregates

This paper discusses the important issue of price level determinacy from a theoretical and empirical perspective. The theoretical section relies basically on a dynamic aggregate demand aggregate supply (AD-AS) model. In the empirical section, we try to assess the relative importance of money against interest rate in explaining the evolution of the price level in six countries: Australia, Canada, Chile, South Korea, New Zealand and the United States

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Introduction

New Keynesians models in which a short-run interest rate is the main instrument of monetary policy gear to attain an inflation rate target, are currently dominant in the academic literature and central bank practice. These models, however, bring back the problem of price level determinacy that was once discussed in the context of an interest rate peg (Sargent and Wallace, 1981). New Classical and New Keynesian economists have tended to favor the Fiscal Theory of the Price Level (FTPL) as a new paradigm of price level determination in economies where central banks manipulate a short-run interest rate to control inflation (Olivo, 2011). These economists emphasize that the quantity theory is not longer valid and that monetary aggregates play no relevant role in the determining the behavior of the price level and inflation.

Woodford (2007) goes further and contents that in the canonical forward looking New Keynesian model with a Taylor rule, the price level is completely determined without any reference to money or the FTPL.

In this paper we share the skepticism of Buiter (1999, 2004) regarding the FTPL, and adopt a "Ricardian" view to analyze theoretically and empirically the direct role of the short-run interest rate and monetary aggregates in the determination of the price level.

The paper is organized in three sections. The first develops a forward-looking aggregate demand – aggregate supply (AD/AS) model to examine price level determination under monetary control and several schemes for setting a short-run interest rate. The second section examines critically Woodford (2007) contention that in the standard forward looking New Keynesian model with a Taylor rule, the price level is determined without any reference to money or the FTPL. The third section presents the results of an empirical analysis based on data for seven countries during a period when their central banks did not monitor monetary aggregates.

1.- Price level determinacy in a dynamic aggregate demand – aggregate supply model

To discuss the topic of price level determinacy with and without money, we first rely on a basic dynamic closed-economy aggregate demand – aggregate supply (AD-AS) with the following structure (Olivo, 2001):

The IS equation is initially expressed as:

$$y_t = k_t + \psi f_t - \alpha r_t \qquad (1)$$

Where y is the logarithm of output, k is a measure of "normal" productive capacity that we assume as exogenous; the variable f measures the real overall fiscal deficit, defined as the logarithm of total government expenditure (including interest payments on the outstanding debt) less the logarithm of lump-sum taxes (g-t).
Using the Fisher equation:

$$r_t = i_t - E_t \pi_{t+1} \quad (2)$$

Or equivalently:

$$r_t = i_t - (E_t p_{t+1} - p_t) \qquad (2a)$$

And substituting it into equation (1) yields:

$$y_t = k_t + \psi f_t - \alpha i_t - \alpha p_t + \alpha E_t p_{t+1} \quad (3)$$

Where i_t is the nominal interest rate, p_t is the logarithm of the price level and $E_t p_{t+1}$ is the expected value of the logarithm of the price level in period t+1 given the information available at period t.

The aggregate supply equation is a Lucas supply function:

$$y_t = k_t + \theta(p_t - E_{t-1} p_t) \qquad (4)$$

1.2.- Price level determinacy with money

The LM equation with all variables in logarithm except the nominal interest rate is given as follows:

$$m_t - p_t = \beta y_t - \lambda i_t \quad (5)$$

Where m_t is the stock of money.

Solving (5) for i_t yields:

$$i_t = (1/\lambda)[\beta y_t - (m_t - p_t)] \quad (5a)$$

Substituting the LM equation (5a) into the IS equation (3) and solving for the level of income, generates the aggregate demand equation:

$$y_t = (\frac{\lambda}{\lambda+\alpha\beta})k_t + (\frac{\lambda\psi}{\lambda+\alpha\beta})f_t + (\frac{\alpha}{\lambda+\alpha\beta})m_t - [\frac{\alpha(1+\lambda)}{\lambda+\alpha\beta}]p_t + (\frac{\lambda\alpha}{\lambda+\alpha\beta})E_t p_{t+1} \quad (6)$$

To solve the model for the price level, we assume that economic agents have perfect foresight, which implies in the aggregate demand equation that $E_t p_{t+1} = p_{t+1}$, and in the aggregate supply equation that $E_{t-1}p_t = p_t$ and $y_t = k_t$.

With these assumptions, setting aggregate demand equal to aggregate supply and solving for the price level produces:

$$p_t = [\frac{\lambda\psi}{\alpha(1+\lambda)}]f_t + [\frac{1}{(1+\lambda)}]m_t - [\frac{\beta}{(1+\lambda)}]k_t + [\frac{\lambda}{(1+\lambda)}]p_{t+1} \quad (7)$$

Iterating forward, we get the following expression:

$$p_t = [\frac{\lambda\psi}{\alpha(1+\lambda)}]\sum_{j=0}^{\infty}(\frac{\lambda}{1+\lambda})^j f_{t+j} + [\frac{1}{(1+\lambda)}]\sum_{j=0}^{\infty}(\frac{\lambda}{1+\lambda})^j m_{t+j} - [\frac{\beta}{(1+\lambda)}]\sum_{j=0}^{\infty}(\frac{\lambda}{1+\lambda})^j k_{t+j} + \lim_{j\to\infty}(\frac{\lambda}{1+\lambda})^{j+1} p_{t+j+1}$$
(8)

This fundamental solution converges if money does not grow too fast relative to "normal" productive capacity, given that the global fiscal deficit cannot grow permanently. With this condition satisfied and $(\frac{\lambda}{1+\lambda}) < 1$, $\lim_{j\to\infty}(\frac{\lambda}{1+\lambda})^{j+1} p_{t+j+1} \to 0$, the price level is determined by the current and discounted future values of the money supply. Thus in a monetary economy, the price level is determined under not very restrictive assumptions. This is a result that is consistent with the quantity theory of money.

1.2.-Price level indeterminacy under an interest rate peg

To study price level determinacy with an interest rate peg, we use the basic model ignoring the LM equation which we substitute for the following condition:

$$i_t = \bar{i} \quad (9)$$

Replacing (9) in equation (3), we obtain the following specification for the aggregate demand equation:

$$y_t = k_t + \psi f_t - \alpha \bar{i} - \alpha p_t + \alpha E_t p_{t+1} \quad (10)$$

Assuming perfect foresight ($E_t p_{t+1} = p_{t+1}$; $E_{t-1} p_t = p_t$), equating aggregate demand (10) and aggregate supply (2), and solving for p_t :

$$p_t = (\psi / \alpha) f_t - \bar{i} + p_{t+1} \quad (11)$$

Iterating forward the solution to this equation is:

$$p_t = (\psi / \alpha) \sum_{j=0}^{\infty} f_{t+j} - \lim_{j \to \infty} j\bar{i} + \lim_{j \to \infty} p_{t+j+1} \quad (12)$$

In equation (12) the term $\lim_{j \to \infty} j\bar{i} \to \infty$ when $\bar{i} > 0$. This implies that this equation does not converge toward a definite value of p_t when the nominal interest rate is pegged at a positive value. Even with $\bar{i} = 0$ equation (12) does not provide a definite solution for p_t because the terminal condition $\lim_{j \to \infty} p_{t+j+1}$ depends on the trajectory of the prices $p_{t+j}, j = 0,1,...,$ which is not determined. This result accords with that obtained by Sargent and Wallace (1981) in their model with rational expectations.

1.3.-Price level indeterminacy under an interest rate rule

To study price level determinacy with a forward-looking interest rate rule, we use the basic model ignoring the LM equation which we substitute for the following reaction function of the monetary authority:

$$i_t = \bar{i} + \delta E_t \pi_{t+1}; \delta > 1 \quad (13)$$

Where $\bar{i}$ is the "natural", "neutral" or long-run nominal interest, and $E_t \pi_{t+1}$ can be interpreted as the deviation of expected inflation with respect to a zero inflation target. Replacing (13) in equation (3), we obtain the following specification for the aggregate demand equation:

$$y_t = k_t + \psi f_t - \alpha \bar{i} - \alpha(1-\delta) p_t + \alpha(1-\delta) E_t p_{t+1} \quad (14)$$

Assuming perfect foresight ($E_t p_{t+1} = p_{t+1}$; $E_{t-1} p_t = p_t$), equating aggregate demand (11) and aggregate supply (2), and solving for p_t :

$$p_t = \left[\frac{\psi}{\alpha(1-\delta)}\right] f_t - \frac{1}{(1-\delta)}\bar{i} + p_{t+1} \quad (15)$$

Iterating forward the solution to this equation is:

$$p_t = \left[\frac{\psi}{\alpha(1-\delta)}\right] \sum_{j=0}^{\infty} f_{t+j} - \frac{1}{(1-\delta)} \lim_{j\to\infty} j\bar{i} + \lim_{j\to\infty} p_{t+j+1} \quad (16)$$

In equation (16) the term $\lim_{j\to\infty} j\bar{i} \to \infty$ when $\bar{i} > 0$. This implies that this equation does not converge toward a definite value of p_t when the nominal "natural" interest rate is a positive value. Even with $\bar{i} = 0$ equation (16) does not provide a definite solution for p_t because the terminal condition $\lim_{j\to\infty} p_{t+j+1}$ depends on the trajectory of the prices $p_{t+j}, j = 0,1,...,$ which is not determined. Thus in the context of the dynamic AD-AS model, a forward-looking interest rate rule produces the same result with respect to price level determination to that obtained with an interest rate peg.

1.4.-The Wicksell – Woodford policy regime

Woodford (2003) shows that under what he calls a Wicksellian policy rule, the rational expectations equilibrium paths of prices and interest rates are (locally) determinate.
A log-linear approximation to the Wicksellian policy rule can be expressed as follows:

$$i_t = \phi(p_{t+1} - p_t^*) \;\; ; \;\; 0 < \phi < 1 \quad (17)$$

Replacing (17) in (3) and assuming perfect foresight yields the following expression for the aggregate demand function:

$$y_t = k_t + \psi f_t - \alpha p_t + \alpha\phi p_t^* + \alpha(1-\phi) p_{t+1} \quad (18)$$

Setting aggregate demand equal to aggregate supply and solving for p_t , we get:

$$p_t = (\psi / \alpha) f_t + \phi p_t^* + (1-\phi) p_{t+1} \qquad (19)$$

Iterating forward yields the following solution:

$$p_t = (\psi / \alpha)\sum_{j=0}^{\infty}(1-\phi)^j f_{t+j} + \phi\sum_{j=0}^{\infty}(1-\phi)^j p_{t+j}^* + \lim_{j\to\infty}(1-\phi)^{j+1} p_{t+j+1} \quad (6)$$

This fundamental solution converges if the price level target does not grow too fast, given that the global fiscal deficit cannot grow permanently. With this condition satisfied and $(1-\phi) < 1$, $\lim_{j\to\infty}(1-\phi)^{j+1} p_{t+j+1} \to 0$, the price level is effectively determined by the current and future discounted target price levels .[1]

1.5.-Discussion of the results with the AD-AS model

Although interest rate pegging and a forward-looking interest rate rule in terms of expected inflation leaves the price level indeterminate, Woodford (2003) shows that there may be a well-defined rational-expectations equilibrium path for the price level, even in a purely cashless economy, under an interest rate policy rule that is formulated in terms of the deviations of the expected price level with respect to a target price level — the Wicksell-Woodford policy regime—.

We raise two objections to Woodford (2003) contention. The first is that among the monetary policy strategies proposed by the New Keynesian, the ones that are actually implemented by central banks are those based on inflation rate targets, not price level targets. Second, actual economies are not cashless economies. Thus, the possibility of a determinate price level under an interest rate rule does not exclude that it is actually the evolution of money what determines the price level. Therefore, we believe that this question cannot be answered by theoretical models alone, but requires empirical testing.

2.-Price level determinacy in a basic New Keynesian Model

We use Woodford (2007) presentation to discuss price level determinacy in the New Keynesian (NK) framework. Woodford (2007) model is composed by two equations plus a Taylor rule:

[1] With 1<ϕ<2, the Wicksell-Woodford rule also produces price level determinacy in the AD-AS model, but with oscillations.

$$y_t = E_t y_{t+1} - \sigma(i_t - E_t \pi_{t+1} - r_t^n) \; (1)$$

$$\pi_t - \overline{\pi_t} = k y_t + \beta(\pi_{t+1} - \overline{\pi}_{t+1}) + u_t \; (2)$$

$$i_t = r_t^* + \overline{\pi_t} + \phi_\pi(\pi_t - \overline{\pi_t}) + \phi_y y_t \; (3)$$

Where:

$y =$ output gap; the log difference between observed output and natural output.

$\pi =$ inflation rate

$\overline{\pi} =$ perceived rate of trend inflation=the central bank´s inflation target

$i =$ short-run nominal interest rate; the riskless rate generated by a money market instrument held between periods t and $t+1$.

r^n = the natural "wicksellian" real interest rate.

r^* = central bank´s perception of the natural real rate

Assuming that both $\overline{\pi_t}$ and r_t^* are exogenous processes – the evolution of which represent shifts in attitudes within the central bank taken to be independent of what is happening with inflation or real activity–, and the Taylor principle holds, the following solution for equilibrium inflation is obtained:

$$\pi_t = \overline{\pi_t} + \sum_{j=0}^{\infty} \psi_j E_t \left[r_{t+j}^n - r_{t+j}^* \right] \; (4)$$

According to Woodford (2007), this shows how inflation is determined by the inflation target of the central bank, and by current and expected future discrepancies between the natural rate of interest and the perception of the central bank of this rate. "So the model does imply a determinate inflation rate". Moreover, given an initial price level, Woodford (2007) argues that the model implies a determinate path for the price level. If t_0 is the first period in which the policy begins to be implemented, a higher price level P_{t_0} will correspond to a higher inflation rate π_{t_0} that will generate a higher interest rate target from the central bank. Given the value of P_{t_0-1}, which is at t_0 a historical fact, there is a uniquely determined equilibrium value for P_{t_0}, and similarly for P_t in any period $t \geq t_0$.

Nelson (2003) have pointed out that the NK model assumption that the steady-state inflation rate $\overline{\pi}$ is an exogenous variable, implies that it only can explain the deviation of observed inflation with respect to its steady-state value. Nelson (2003) argues that the steady-state inflation rate is not an exogenous variable, but is determined by the steady-state growth rate of money in the economy. Hence, Friedman contention that inflation is always and everywhere a monetary phenomenon, continues to be valid in the NK model. A corollary of this discussion is that because the NK model can only determine deviations of the actual inflation rate relative to its steady-state value, it cannot explain either the steady-state or trend price level. At most, it could determine the deviations of the observed price level with respect to its steady-state trajectory.

In addition, Woodford (2007) story of how the NK model can determine the price level, assumes that P_{t_0-1} and previous values of the price level are a historical fact when the monetary policy regime based on a Taylor rule is introduced. The question here is how the introduction of the Taylor rule in period t_0 invalidates the process that determined P_{t_0-1} and previous price levels.

3.-Empirical analysis

In this section we try to assess empirically the relative importance of money against interest rate in explaining the evolution of the price level in six countries: Australia, Canada, Chile, South Korea, New Zealand and the United States. We first pool quarterly data for these countries for different periods, and then proceed to a country by country analysis.

The selection of these countries was primarily motivated by the fact that their central banks have given little consideration to monetary aggregates in their monetary policy strategies during the period under study. Five of them are inflation targeters: Australia adopted Inflation Targeting (IT) in 1993; Canada in 1991; Chile in 1991; Korea in 1997; and New Zealand in 1989. In the United States the FED has kept its tradition of not binding its monetary policy strategy to any specific framework. A second criterion for the choice of countries was data availability.

We obtained quarterly data up to 2007 from the IMF-IFS data base to reduce potential inconsistencies in the information for the different countries.

For the price level (P), we rely on the consumer price indexes with 2000 as the base year. For the monetary aggregates, we construct indexes with 2000 as the base year for the monetary base (or Reserve Money in the IMF-IFS terminology), M1 (money in the banking survey), and M2 (money plus quasi money in the banking survey). For the interest rate, we employ the money market interest rate when available.[2] In the econometric estimations, we include the price level and monetary aggregates data in logarithms.

3.1.-Panel data analysis

We use the following panel unit root tests available in EViews (Appendix 1): Levin, Lin, Chu; Breitung (Common root); Im, Pesaran, Shin; Fisher - ADF; and Fisher - PP (Individual roots). All unit root tests applied to our unbalanced panel indicates that the log of the price level, including individual linear trends, is stationary at statistical significance levels below 10%. In the case of monetary aggregates, only the log of the M1index (LIM1), including individual linear trends, is stationary according to all panel unit root tests, except Breitung. The log of the M2 index (LIM2) and the monetary base (LIRM) contain a unit root according to all the tests that we employ, even including individual linear trends. For the nominal money market rate is possible to reject the null of a unit root with all the tests, with only individual effects.

Given these results, we estimate a simple dynamic equation and a VAR model relating the logarithm of the price level (LP), the logarithm of the M1index (LIM1), and the money market interest rate (I).

Estimation of an equation for LP with fixed cross-section coefficients using GMM, generates the results shown in Table 1. In this case we find that the coefficient LIM1 is positive and statistically significant, while the coefficient of the money market interest rate (I) is statistically different from zero, but positive. This last result reflects the presence of the so-called "price puzzle" (Walsh, 2010) regarding the effect of the interest rate on the price level, which have been reported by several authors. Inclusion of the output gap generates a negative and not significant coefficient, and does not alter the aforementioned results for the other variables.

[2] In the case of Chile, we use the average discount rate until 2000 when data of the money market rate is available.

Table 1
Dependent Variable: LP
Method: Panel Generalized Method of Moments
Date: 04/11/11 Time: 18:20
Sample (adjusted): 1990Q1 2007Q4
Periods included: 72
Cross-sections included: 6
Total panel (unbalanced) observations: 358
2SLS instrument weighting matrix
White cross-section standard errors & covariance (d.f. corrected)
Instrument specification: C LP(-2) LP(-3) LP(-4) LIM1(-1) LIM1(-2) LIM1(-3)
LIM1(-4) I(-1) I(-2) I(-3) I(-4)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.041958	0.025204	1.664775	0.0969
LIM1	0.005539	0.001034	5.358176	0.0000
I	0.000740	0.000235	3.149126	0.0018
LP(-1)	0.985820	0.005749	171.4778	0.0000
	Effects Specification			
Cross-section fixed (dummy variables)				
R-squared	0.998068	Mean dependent var		4.608627
Adjusted R-squared	0.998024	S.D. dependent var		0.119389
S.E. of regression	0.005307	Sum squared resid		0.009829
Durbin-Watson stat	1.721673	J-statistic		25.02424
Instrument rank	17			

We also estimate a Panel VAR with fixed coefficients and five lags (Appendix 2). The panel VAR includes the relevant variables in the following order: I, LIM1, LYG, LP. From the impulse-response functions —using the Cholesky decomposition—, we find that a positive shock (one standard error) to the money market interest rate has a positive and statistically significant impact on the price level (LP) — the "price puzzle"—. Shocks to LIM1 and the output gap (LYG) have a positive and statistically significant impact on the price level as expected. It is important to note that using the Generalized impulse-response functions do not change these results substantially. Thus in general, the results obtained with our panel data indicate that money seems to have a clearer influence on the price level than the money market interest rate.

3.2.-Time series analysis

Although the panel data analysis allowed us to dispose of a much larger sample with its econometric advantages, it also may hide non trivial differences in the data of each of the six countries we are studying. For this reason, we also try to analyze the data for each country separately. As in the panel data analysis, we begin with simple regression models and then move to VAR models. Results in this case should be interpreted with care due to the relatively small samples available.

a) Australia

In the case of Australia, we find that it is not possible to reject the null hypothesis that LP contains a unit root using Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Zivot-Andrews (ZV one break) tests. In contrast, for LIM1 and the interest rate (I), it is possible to reject the null that they contain a unit root. Thus, a cointegration relationship between the log price level and these variables does not exist. Only for LIRM and LIM2 it is not possible to reject the null that they contain a unit root based on ADF, PP, and ZV tests (Appendix 3).

Given these results, we test for a cointegration relationship between LP and LIM2. We obtained the best results by including the log of M2 velocity, which is not stationary, in the cointegration relation:

Table2

Dependent Variable: LP_AUS
Method: Canonical Cointegrating Regression (CCR)
Date: 05/16/11 Time: 10:34
Sample (adjusted): 1993Q3 2007Q4
Included observations: 58 after adjustments
Cointegrating equation deterministics: C
Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LIM2_AUS	0.571406	0.050888	11.22862	0.0000
LV2_AUS	0.897753	0.158381	5.668309	0.0000
C	2.839760	0.087654	32.39735	0.0000

R-squared	0.984295	Mean dependent var	4.627687
Adjusted R-squared	0.983724	S.D. dependent var	0.112562
S.E. of regression	0.014361	Sum squared resid	0.011342
Durbin-Watson stat	1.330366	Long-run variance	0.000413

The Engle-Granger test on the residuals of this equation indicates that they are stationary at a 5% level of statistical significance.

Thus for Australia, we find evidence that money cointegrates with the price level, with an elasticity coefficient of 0.57. We could not find, however, a cointegration relationship between the price level and Reserve Money, despite both being I(1).

Additionally, we estimate a VAR model for Australia with six lags and the following order of the relevant variables: I, LIM1 and LP (Appendix 4). It was not possible to

obtain a stable VAR including LIM2.Also, the inclusion of the output gap made the VAR model unstable.
A one standard deviation shock to the money market rate (I) has a positive impact on the price level (the “price puzzle”), although it is not statistically significant. A one standard deviation shock to LIM1 has a positive shock on the logarithm of the price level, but this effect is only significant at the very beginning of the forecast period. The generalized impulse response functions suggest that the previous results do not depend substantially on the ordering of the variables imposed on the model. In general, the results from the VAR model suggest that money has a weak impact on the determination of the price level, while the money market rate has no discernable effect.

b) Canada

In the case of Canada, we find that for the log of the price level (LP) we cannot reject the null hypothesis that it contains a unit root with any of the tests employed. For the log of the monetary aggregates the null of a unit-root can be rejected: for LIRM with the PP test, and for LIM1 and LIM2 with the ZV test. For the money market interest rate (I), the null of a unit root can be rejected using the ADF and PP tests including only an intercept term . These results imply, that in principle, we cannot establish a robust empirical relationship between the price level and the relevant variables for Canada (Appendix 3).
We can still, however, use a VAR model and analyze the impulse- response functions. We estimate a VAR model with three lags and the following order of the variables: the money market interest rate (I), LIM1, the output gap (LYG), and LP.
The impulse response functions (Appendix 5) indicate that a one standard deviation shock to the money market rate (I) has no significant effect on the log of the price level. A one standard deviation shock to LIM1 has a positive but statistically insignificant impact on the log of the price level. A one standard deviation shock to the output gap has a positive and statistically significant impact on the price level.
The results are very similar using Reserve Money, but with M2 it was not possible to obtain a stable VAR model. When using the Generalized impulse-response functions, the results are not substantially different. .
Thus in general, we conclude that for Canada neither the money market interest rate or LIM1 have a relevant influence on the price level. We find the results for Canada puzzling.

c) Chile

In Chile the log of the price level (LP) is stationary including a time trend according to the PP test. The ADF and PP tests indicate that the log of M1 (LIM1) is stationary including a time trend. The logs of Reserve Money (LIRM) and M2 (LIM2) contain a unit root according to the ADF, PP, and ZV tests. Both the ADF and PP tests suggest that the money market rate (I) is stationary with only an intercept term. (Appendix 3). With these results, we estimate a dynamic equation of the logarithm of the price level (LP) against the logarithm of the M1 index (LIM1), and the money market interest rate. After eliminating the variables with coefficients with p-values greater than 0.2 sequentially, we obtain the following results:

Table 3

Dependent Variable: LP_CHI
Method: Least Squares
Date: 04/04/11 Time: 16:56
Sample (adjusted): 1994Q2 2007Q4
Included observations: 55 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.200984	0.087120	2.306992	0.0255
LIM1_CHI(-2)	0.026087	0.006334	4.118485	0.0002
I_CHI	0.000905	0.000312	2.901058	0.0056
I_CHI(-1)	-0.000566	0.000300	-1.887901	0.0652
I_CHI(-2)	0.000830	0.000276	3.012389	0.0042
LP_CHI(-1)	1.261941	0.120100	10.50746	0.0000
LP_CHI(-2)	-0.745466	0.191676	-3.889200	0.0003
LP_CHI(-3)	0.413541	0.128152	3.226948	0.0023

R-squared	0.999066	Mean dependent var	4.595969
Adjusted R-squared	0.998927	S.D. dependent var	0.149256
S.E. of regression	0.004890	Akaike info criterion	-7.669466
Sum squared resid	0.001124	Schwarz criterion	-7.377490
Log likelihood	218.9103	Hannan-Quinn criter.	-7.556556
F-statistic	7179.729	Durbin-Watson stat	2.034965
Prob(F-statistic)	0.000000		

The coefficient of LIM1 is positive and statistically different from zero as expected, while the sum of the coefficients of the short-run interest rate (I) is positive and significantly different from zero (the "price puzzle"). The coefficient of the output gap (LYG) contemporaneous or lagged one period was not statistically significant.

We also estimate a VAR model with four lags and the relevant variables in the following order: I, LIM1, LP (Appendix 6). We exclude the output gap to obtain a stable VAR.

We find that a one standard deviation shock to the money market rate has a positive impact on the price level that is significant at the beginning of the forecast period (the "price puzzle"). A one standard deviation shock to LIM1 has a positive impact on LP that is initially not significant, but as the forecast period advances it turns significant. Using the Generilized impulse-response functions instead of the Cholesky decomposition, we notice that the results do not change substantially, though the impact of a shock to money on LP is weaker.

In general in the case of Chile, we conclude that the price level seems to be more closely related to M1 than to the short-interest rate manipulated by the central bank.

d) Korea

For Korea the unit-root tests (Appendix 3) indicate that LP is stationary using the ADF with a linear trend. The log of Reserve Money (LIRM) and M1 (LIM1) are stationary according to both ADF and PP tests; LIM2 contains a unit root even when we apply the ZV test that considers a one-brake. The money market rate (I) is stationary according to the ADF test including only an intercept .

Given the results from the unit-root tests, we estimate a dynamic equation for the logarithm of the price level (LP), the logarithm of the Reserve Money index (LIRM), and the money market interest rate (I). After trimming down the non significant coefficients, we obtain the results in Table 4. The coefficient of LIRM lagged one period is positive and statistically significant. The sum of the coefficients of the money market interest rate (I) is positive and statistically different from zero (the "price puzzle"). The coefficient of the output gap contemporaneous or lagged one period is not statistically relevant.

Table 4

Dependent Variable: LP_KOR
Method: Least Squares
Date: 04/04/11 Time: 17:27
Sample (adjusted): 1997Q3 2007Q4
Included observations: 42 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.195369	0.124981	1.563188	0.1268
LIRM_KOR(-1)	0.026659	0.012517	2.129829	0.0401
I_KOR	0.002721	0.000490	5.550771	0.0000
I_KOR(-1)	-0.001481	0.000519	-2.854898	0.0071
LP_KOR(-1)	0.724132	0.131668	5.499695	0.0000
LP_KOR(-2)	0.207140	0.123830	1.672776	0.1030

R-squared	0.996772	Mean dependent var	4.682006
Adjusted R-squared	0.996323	S.D. dependent var	0.091365
S.E. of regression	0.005540	Akaike info criterion	-7.422089
Sum squared resid	0.001105	Schwarz criterion	-7.173851
Log likelihood	161.8639	Hannan-Quinn criter.	-7.331100
F-statistic	2223.090	Durbin-Watson stat	2.145803
Prob(F-statistic)	0.000000		

We estimate a VAR system with four lags and the relevant variables in the following order: I, LIRM, LYG, LP (Appendix 7) .

The impulse –response functions indicate that a one standard deviation shock to the short-term interest rate has a positive and statistically significant influence on LP at the beginning of the forecast period (the "Price Puzzle"). A shock to Reserve Money has a positive but no statistically significant impact on LP. A one standard deviation shock to the output gap (LYG) exhibit a positive and statistically significant effect on the price level (LP) at the beginning of the forecast period .

In general, we interpret the results for Korea as indicating that money has a clearer influence on the price level than the short-run interest, though in the VAR model only the output gap presents a consistent effect on the price level.

e) New Zealand

The data from New Zealand indicates that the log of the price level is stationary according to both ADF and PP tests, including a linear trend. The logs of Reserve Money and M1 are stationary when we apply a ZV test, while LIM2 contains a unit root according to all tests. The ADF test indicates that the money market interest rate (I) is stationary including only an intercept. (Appendix 3).

We then estimate a dynamic equation of the logarithm of the price level (LP) against the the logarithm of the Reserve Money index (LIRM), and the money market rate (I). After eliminating non-significant coefficients, we obtain:

Table 5

Dependent Variable: LP_NEZ
Method: Least Squares
Date: 04/04/11 Time: 18:17
Sample (adjusted): 1990Q1 2007Q4
Included observations: 72 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.055861	0.042997	1.299173	0.1985
LIRM_NEZ(-2)	0.003285	0.001905	1.724629	0.0893
I_NEZ	0.000905	0.000601	1.505908	0.1369
I_NEZ(-1)	0.001479	0.000887	1.667821	0.1002
I_NEZ(-2)	-0.002308	0.000558	-4.137506	0.0001
LP_NEZ(-1)	1.085089	0.050268	21.58604	0.0000
LP_NEZ(-4)	-0.099766	0.052623	-1.895855	0.0624

R-squared	0.999001	Mean dependent var	4.593457
Adjusted R-squared	0.998909	S.D. dependent var	0.105307
S.E. of regression	0.003479	Akaike info criterion	-8.392062
Sum squared resid	0.000787	Schwarz criterion	-8.170720
Log likelihood	309.1142	Hannan-Quinn criter.	-8.303945
F-statistic	10832.08	Durbin-Watson stat	2.046214
Prob(F-statistic)	0.000000		

The coefficient of LIRM(-2) is statistically significant at a 10% level (p-value 0.09). The sum of the coefficients of the money market interest rate is positive and significantly different from zero (p value=0.1066), contrary to what we expect theoretically (the “price puzzle”).

We estimate a VAR model with two lags and the variables in the following order: I, LIRM, LYG, and LP (Appendix 8). We also include a dummy variable for 2005.Q1 as an exogenous variable.

In this VAR a one standard deviation shock to the money market rate (I) has a positive but statistically non significant impact on the price level (LP). A one standard deviation shock to LIRM has a positive but statistically non significant effect on LP. A one standard deviation shock to the output gap (LYG) has a positive impact on LP that is statistically significant for several periods of the forecast horizon. The results do not vary markedly with the generalized impulse-response functions.

Thus for New Zealand, we find evidence that monetary aggregates have a more consistent impact on the price level than the short-run interest rate with a single equation, but with a VAR model only the output gap exhibits an influence on the price level.

f) United States

The data for the United States indicates that the log of the price level is stationary according to both the ADF and PP tests, including a linear trend. The log of Reserve Money is stationary with the PP test considering a linear trend, while the log of M1 is stationary according to the ADF test (with a linear trend), and the PP test (without a linear trend). All tests employed suggest that the log of M2 contains a unit-root. The ADF test indicates that money market rate is stationary, including only an intercept. (Appendix 3).

Given this analysis of the individual series, we estimate the following dynamic model of the logarithm of the price level (LP) against the logarithm of the Reserve Money index (LIRM), and the money market interest rate:

Table 6

Dependent Variable: LP_USA
Method: Least Squares
Date: 04/12/11 Time: 11:14
Sample (adjusted): 1990Q1 2007Q4
Included observations: 72 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.122423	0.071025	1.723655	0.0896
LIRM_USA(-2)	0.016554	0.010608	1.560467	0.1236
I_USA(-1)	0.001851	0.001032	1.792759	0.0777
I_USA(-2)	-0.001468	0.001026	-1.430613	0.1574
LP_USA(-1)	1.250419	0.116728	10.71225	0.0000
LP_USA(-2)	-0.716581	0.168685	-4.248040	0.0001
LP_USA(-3)	0.870092	0.176446	4.931204	0.0000
LP_USA(-4)	-0.446287	0.118929	-3.752559	0.0004

R-squared	0.999345	Mean dependent var	4.565371
Adjusted R-squared	0.999273	S.D. dependent var	0.134864
S.E. of regression	0.003637	Akaike info criterion	-8.291015
Sum squared resid	0.000846	Schwarz criterion	-8.038052
Log likelihood	306.4765	Hannan-Quinn criter.	-8.190309
F-statistic	13939.24	Durbin-Watson stat	1.936542
Prob(F-statistic)	0.000000		

In this case the coefficient of LIRM(-2) is positive and statistically significant with a p-value of 0.12, while the sum of the coefficients of the money market interest rate is not significantly different from zero.

For the US economy we estimate a VAR model with four lags and the variables in the following order: I, LIRM, LYG, and LP (Appendix 9).

A one standard deviation shock to the money market rate (I) presents a positive, but not statistically significant effect on LP. A one standard deviation shock to Reserve Money (LIRM) exhibits a positive impact on LP, but this effect only becomes statistically significant with a considerable lag during the forecast horizon. A one standard deviation shock to the output gap has a positive, but not statistically significant impact on LP. These results do not change substantially when the Generalized impulse-response functions are used.

From these results we conclude that for the United States, money exhibits a more consistent influence on the price level than the money market rate.

Conclusions

In this paper we examine the issue of price level determinacy from a theoretical and empirical perspective. In this study we adopt the "Ricardian" view that holds that the inter-temporal government budget constraint is always satisfied.

From a theoretical point of view, the dynamic aggregate-demand – aggregate-supply (AD-AS) model that we use, produces the typical results that control of a monetary aggregate generates price level determinacy under conditions that are not very restrictive, while under an interest rate peg the price level is indeterminate. An interest rate rule that reacts to expected inflation also leaves the price level indeterminate in the AD-AS framework. Only the Woodford-Wicksell interest rate rule is consistent with price level determinacy, but central banks in practice follow inflation targets not price level targets as this rules formulates. We also discuss critically the conclusions with respect to price level determinacy in the canonical New Keynesian model as presented by Woodford (2007). We believe that Woodford arguments with respect to price level determinacy in this model are not robust. Particularly, his reasoning does not discard the possibility that the price level is still determined by the behavior of the money supply, even if a Taylor-type interest rule is being implemented by the central bank.

From an empirical point of view, we try to assess the relative importance of money against interest rate in explaining the evolution of the price level in six countries: Australia, Canada, Chile, South Korea, New Zealand and the United States. We first pool quarterly data for these countries for different periods up to 2007, and then proceed to a country by country analysis. The selection of these countries was primarily motivated by the fact that their central banks have given little consideration to monetary aggregates in their monetary policy strategies during the period under study.

We find in our single equation models —with panel data and individual countries' series— that monetary aggregates have, in most cases, positive and statistically significant impacts on the price level: Panel (M1), Australia (M2), Chile (M1), Korea (Reserve Money), New Zealand (Reserve Money), and the USA (Reserve Money). The short-run interest rate frequently exhibits a positive and statistically significant influence on the price level consistent with the "price puzzle": Chile, Korea, and New Zealand.

The VAR model with panel data shows in the impulse –response function analysis the presence of the "price puzzle" phenomenon. In the VAR models for individual countries, the "price puzzle" is statistically significant in the cases of Chile and Korea. In the panel VAR model a shock to money measured through M1 presents a positive and statistically significant influence on the price level. In the VAR models for individual countries, shocks to the different measures of money that we employ (Reserve Money, M1, and M2) always have a positive impact on the price level, but this influence is only statistically significant in the cases of Chile (M1) and the United States (Reserve Money).

It is also interesting to point out that the VAR models with panel data and for individual countries show a very weak response of the short-run interest rate to shocks to the price level.

Our general conclusion is that, though the time span of our empirical models is not enough for a long-run analysis, they capture a glimpse of the operation of the Quantity Theory. Thus we content that the Quantity Theory continues to be relevant and that monetary policy strategies should not ignore completely the behavior of monetary aggregates (Issing, 2011).

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Appendix

1.- Unit-root tests panel data

Panel unit root test: Summary
Series: LP
Date: 05/24/11 Time: 11:32
Sample: 1989Q1 2007Q4
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 3
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-2.27748	0.0114	6	369
Breitung t-stat	-2.09804	0.0180	6	363
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-1.59498	0.0554	6	369
ADF - Fisher Chi-square	20.7979	0.0534	6	369
PP - Fisher Chi-square	32.1633	0.0013	6	376

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: LIM1
Date: 05/24/11 Time: 11:31
Sample: 1989Q1 2007Q4
Exogenous variables: Individual effects, individual linear trends
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 8
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-2.46020	0.0069	6	359
Breitung t-stat	-0.72128	0.2354	6	353
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-2.53866	0.0056	6	359
ADF - Fisher Chi-square	24.8478	0.0156	6	359
PP - Fisher Chi-square	40.2532	0.0001	6	376

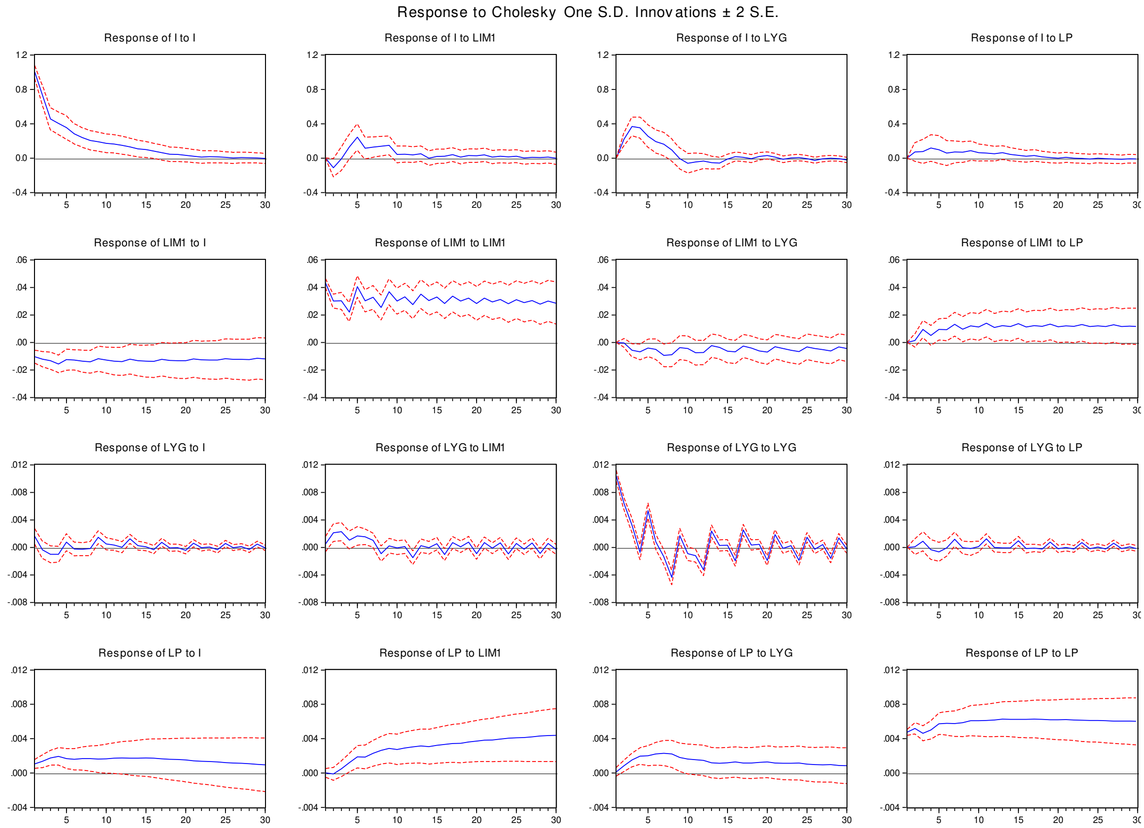
** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Panel unit root test: Summary
Series: I
Date: 05/25/11 Time: 18:54
Sample: 1989Q1 2007Q4
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 1 to 7
Newey-West automatic bandwidth selection and Bartlett kernel

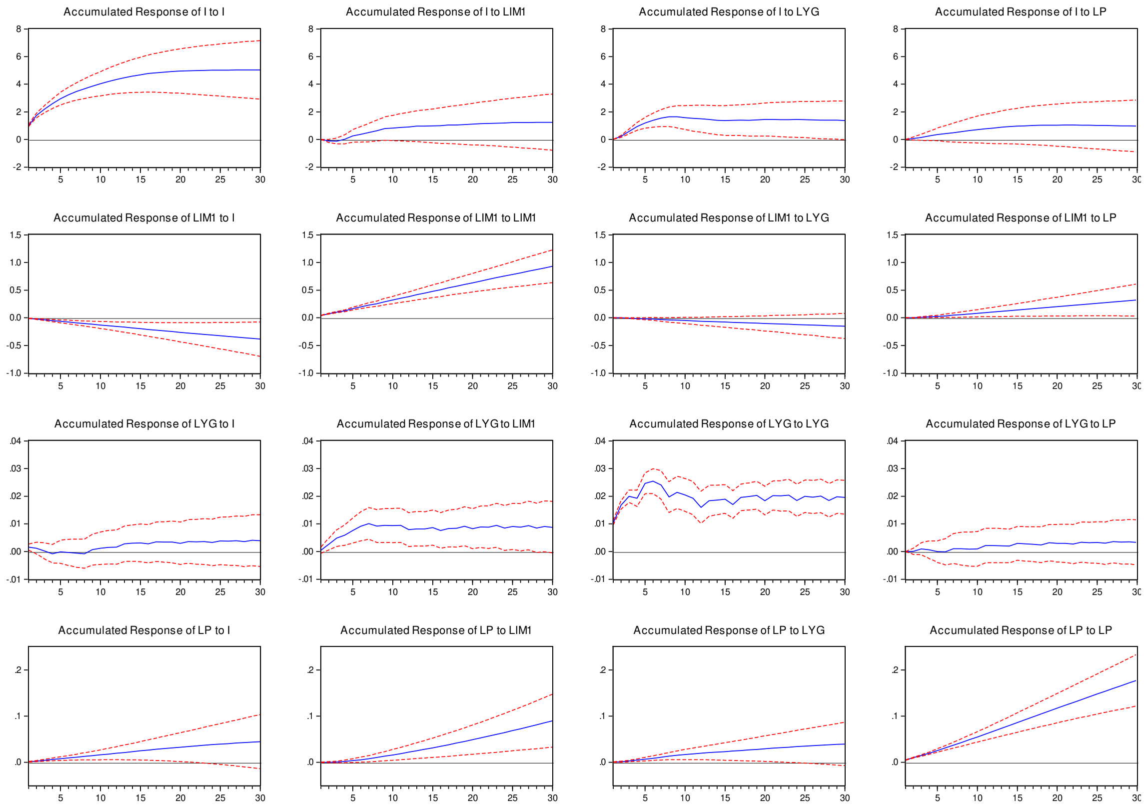
Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.80213	0.0001	6	364
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-4.50348	0.0000	6	364
ADF - Fisher Chi-square	42.8898	0.0000	6	364
PP - Fisher Chi-square	34.5726	0.0005	6	376

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

2.- Panel data VAR



Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.



3.- Unit-root tests time series individual countries

Australia

	DF	PP	ZA
LP	-1.47	-1.88	-3.82
LIRM	-2.62	-2.62	-3.82
LIM1	-3.63 **	-2.31	
LIM2	1.65	3.23	0
I	-3.03 **	-2.08	

Canada

	DF	PP	ZA
LP	-1.73	-1.73	-3.76
LIRM	-2.30	-8.26 *	
LIM1	-2.17	-2.02	-5.36 **
LIM2	-2.02	-2.07	-12.28 *
I	-3.59 *	-3.48 **	

Chile

	DF	PP	ZA
LP	-2.77	-4.53 *	
LIRM	-2.29	-2.18	-3.06
LIM1	-3.26 ***	-6.81 *	
LIM2	-1.92	-1.92	-3.26
I	-3.11 **	-4.23 *	

Korea

	DF	PP	ZA
LP	-3.21 ***	-3.17	
LIRM	-4.03 **	-4.08 **	
LIM1	-3.42 ***	-4.07 **	
LIM2	-0.83	-0.55	0
I	-2.70 ***	-1.81	

New Zealand

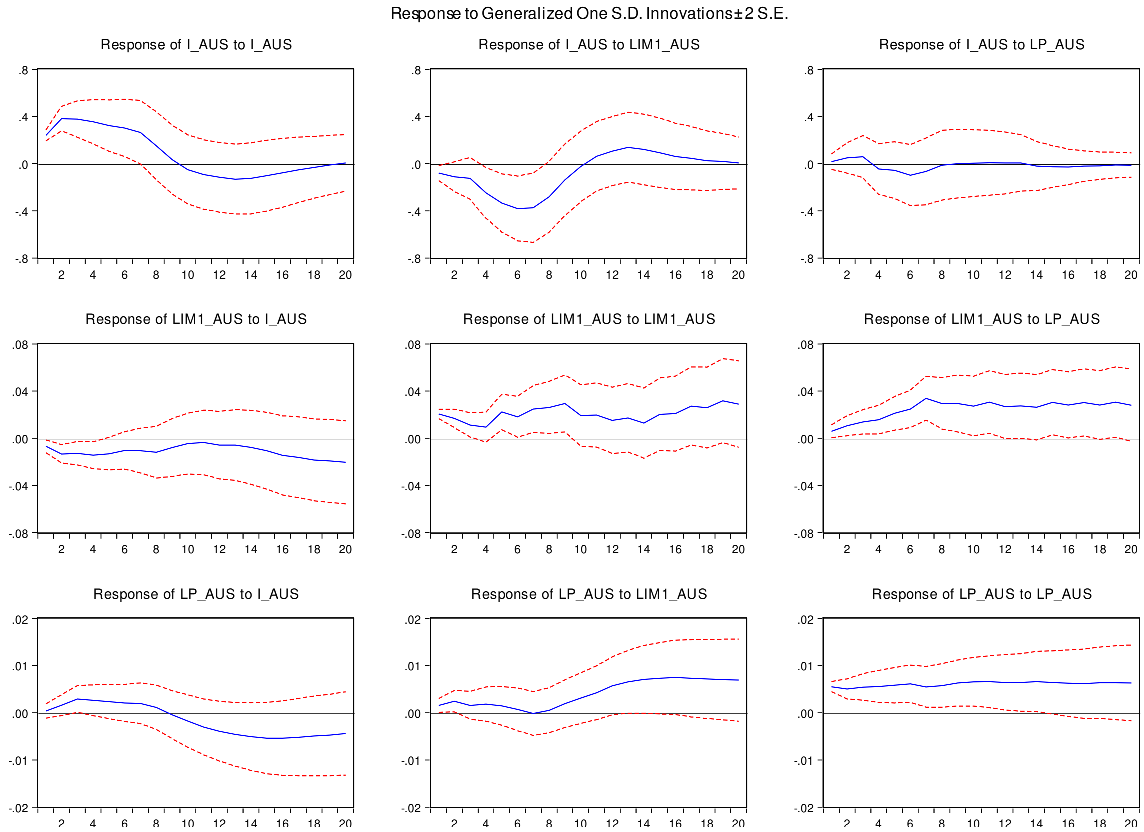
	DF	PP	ZA
LP	-3.29 ***	-3.42 ***	
LIRM	-2.02	-1.45	-5.20 **
LIM1	-2.07	-1.77	-4.14 ***
LIM2	-1.42	-1.29	-3.04
I	-2.95 **	-2.33	

USA

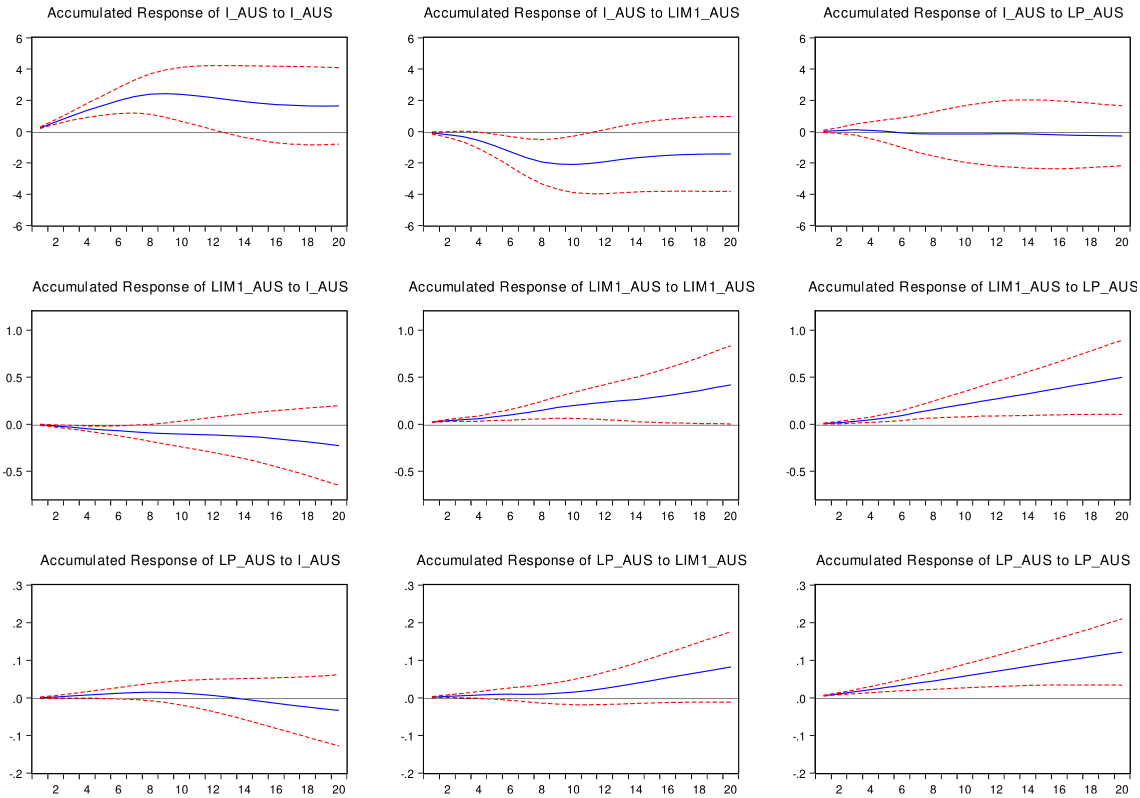
	DF	PP	ZA
LP	-3.66 **	-4.03 **	
LIRM	-1.26	-3.86 **	
LIM1	-3.29 ***	-2.34	
LIM2	-0.95	-1.05	-3.21
I	-3.43 **	-2.45	

*** 10%; ** 5%; * 1%

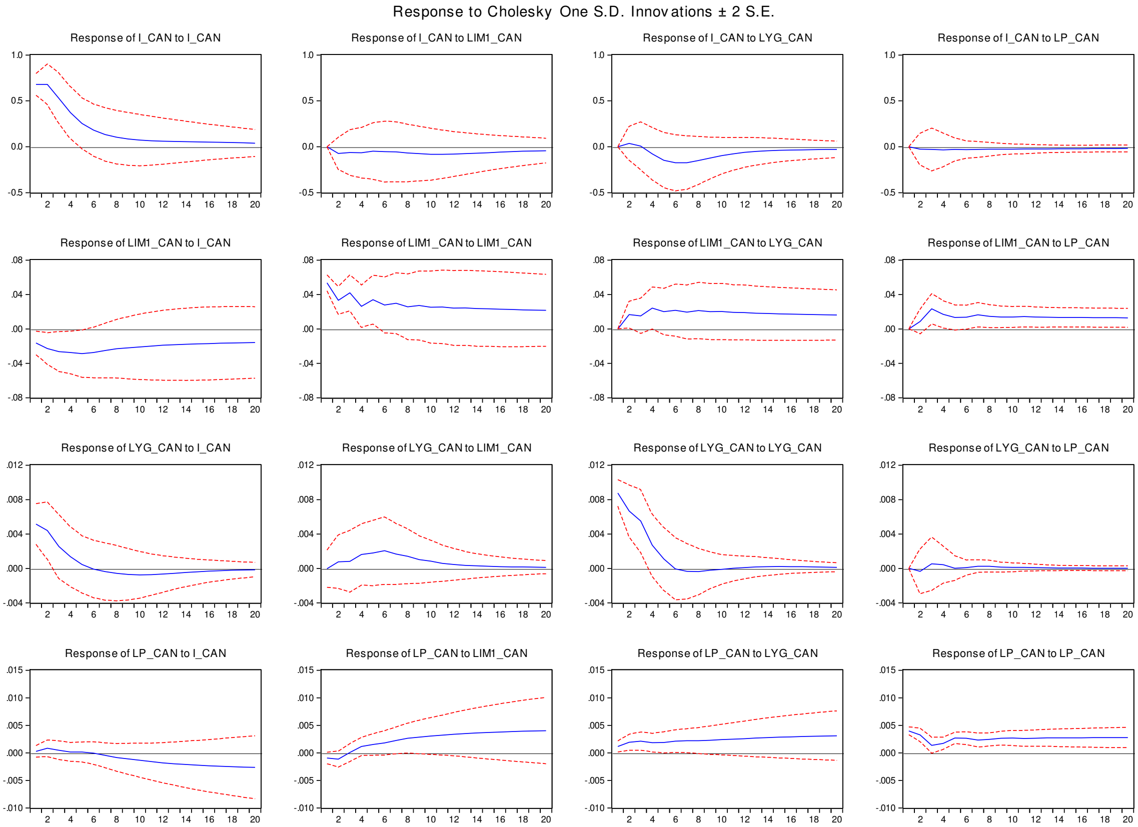
4.- VAR Australia

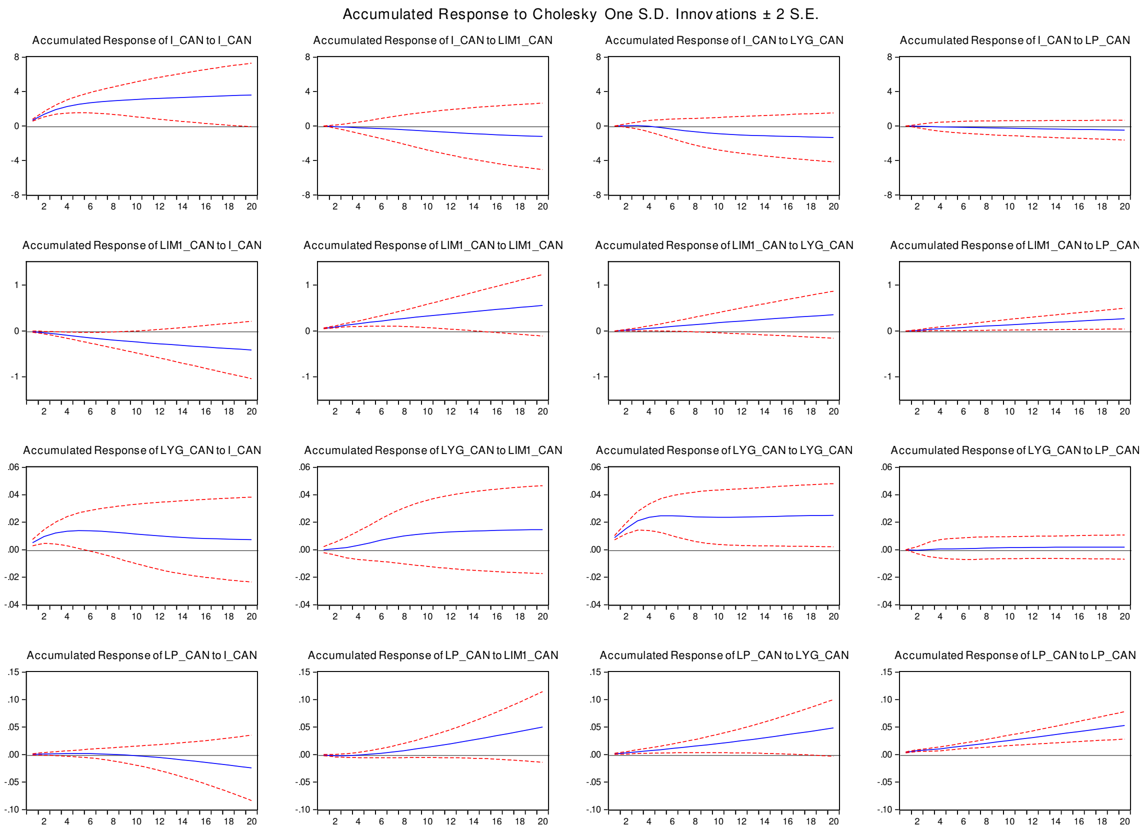


Accumulated Response to Generalized One S.D. Innovations ± 2 S.E.

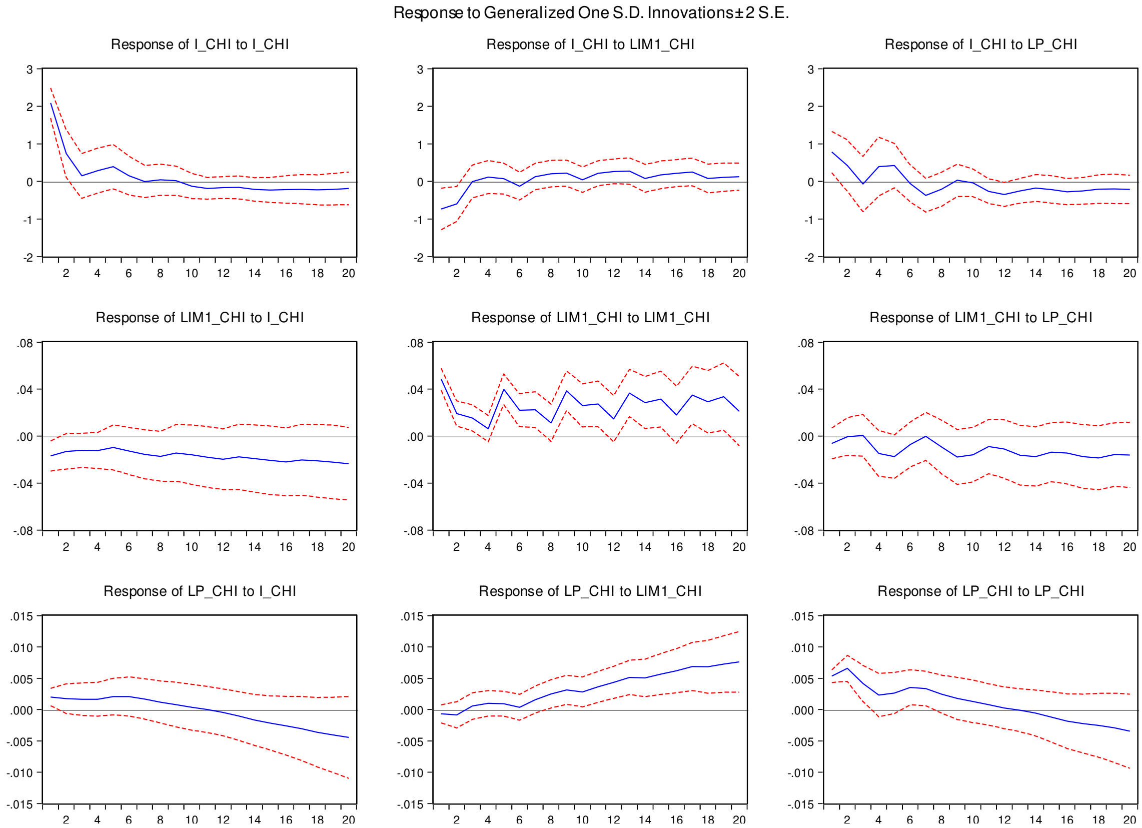


5.- VAR Canada

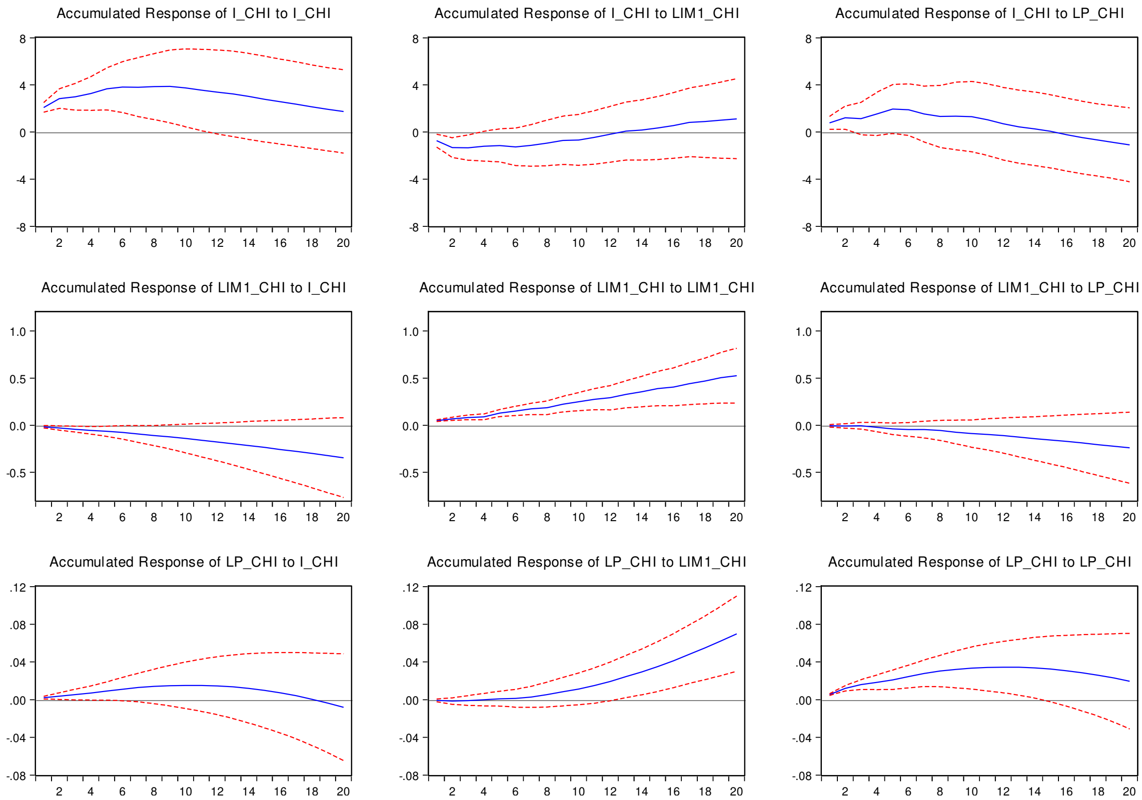

Response to Cholesky One S.D. Innovations ± 2 S.E.
Response of I_CAN to I_CAN
Response of I_CAN to LIM1_CAN
Response of I_CAN to LYG_CAN
Response of I_CAN to LP_CAN
Response of LIM1_CAN to I_CAN
Response of LIM1_CAN to LIM1_CAN
Response of LIM1_CAN to LYG_CAN
Response of LIM1_CAN to LP_CAN
Response of LYG_CAN to I_CAN
Response of LYG_CAN to LIM1_CAN
Response of LYG_CAN to LYG_CAN
Response of LYG_CAN to LP_CAN
Response of LP_CAN to I_CAN
Response of LP_CAN to LIM1_CAN
Response of LP_CAN to LYG_CAN
Response of LP_CAN to LP_CAN


Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.
Accumulated Response of I_CAN to I_CAN
Accumulated Response of I_CAN to LIM1_CAN
Accumulated Response of I_CAN to LYG_CAN
Accumulated Response of I_CAN to LP_CAN
Accumulated Response of LIM1_CAN to I_CAN
Accumulated Response of LIM1_CAN to LIM1_CAN
Accumulated Response of LIM1_CAN to LYG_CAN
Accumulated Response of LIM1_CAN to LP_CAN
Accumulated Response of LYG_CAN to I_CAN
Accumulated Response of LYG_CAN to LIM1_CAN
Accumulated Response of LYG_CAN to LYG_CAN
Accumulated Response of LYG_CAN to LP_CAN
Accumulated Response of LP_CAN to I_CAN
Accumulated Response of LP_CAN to LIM1_CAN
Accumulated Response of LP_CAN to LYG_CAN
Accumulated Response of LP_CAN to LP_CAN

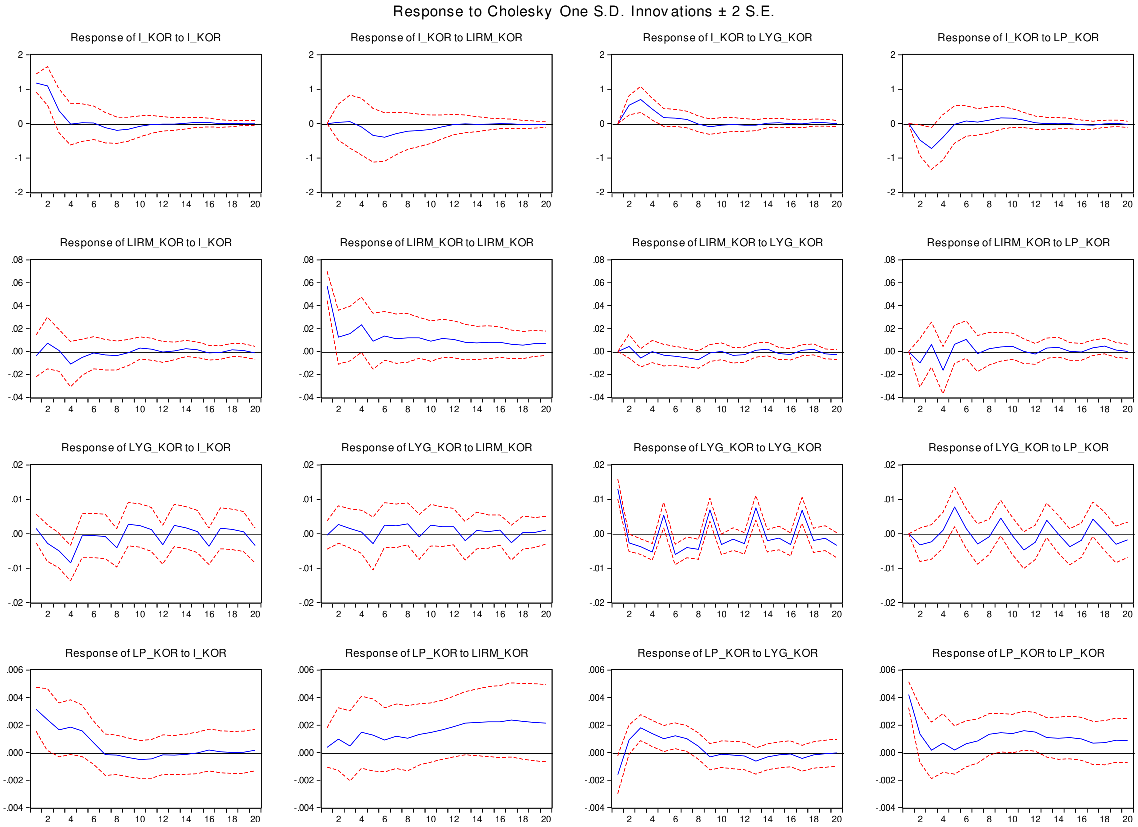
6.- VAR Chile


Response to Generalized One S.D. Innovations ± 2 S.E.
Response of I_CHI to I_CHI
Response of I_CHI to LIM1_CHI
Response of I_CHI to LP_CHI
Response of LIM1_CHI to I_CHI
Response of LIM1_CHI to LIM1_CHI
Response of LIM1_CHI to LP_CHI
Response of LP_CHI to I_CHI
Response of LP_CHI to LIM1_CHI
Response of LP_CHI to LP_CHI

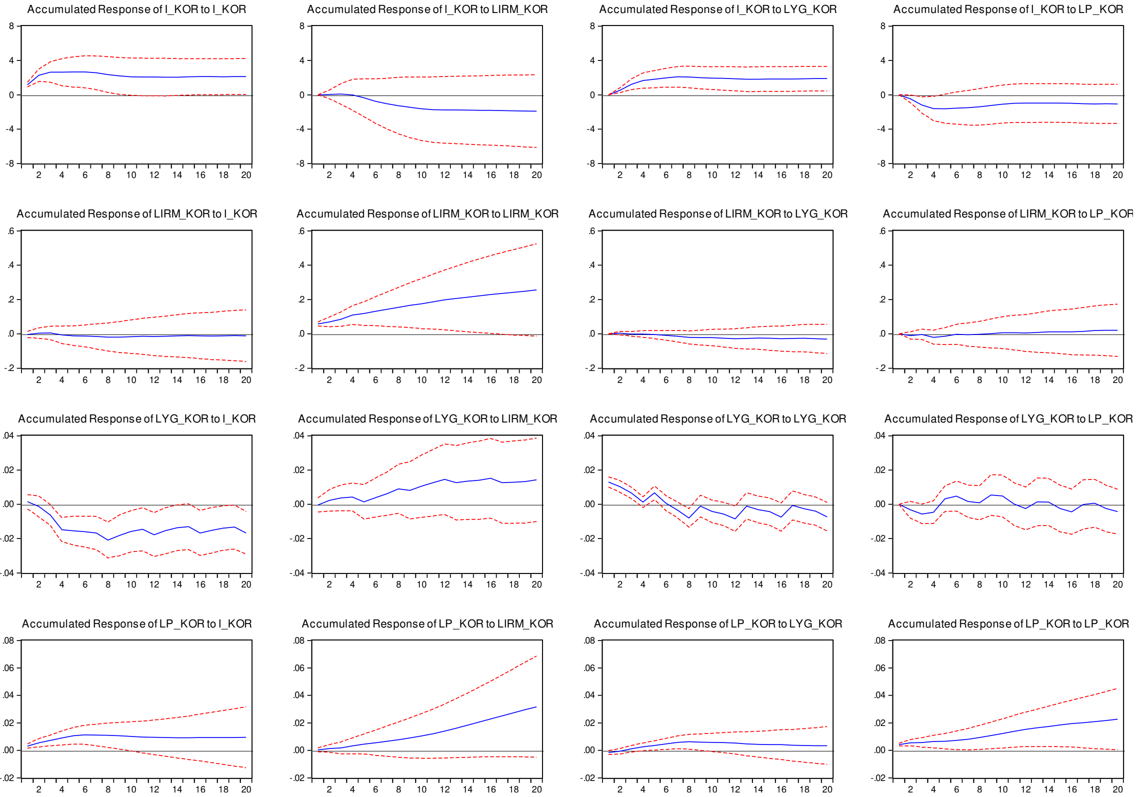
Accumulated Response to Generalized One S.D. Innovations±2 S.E.



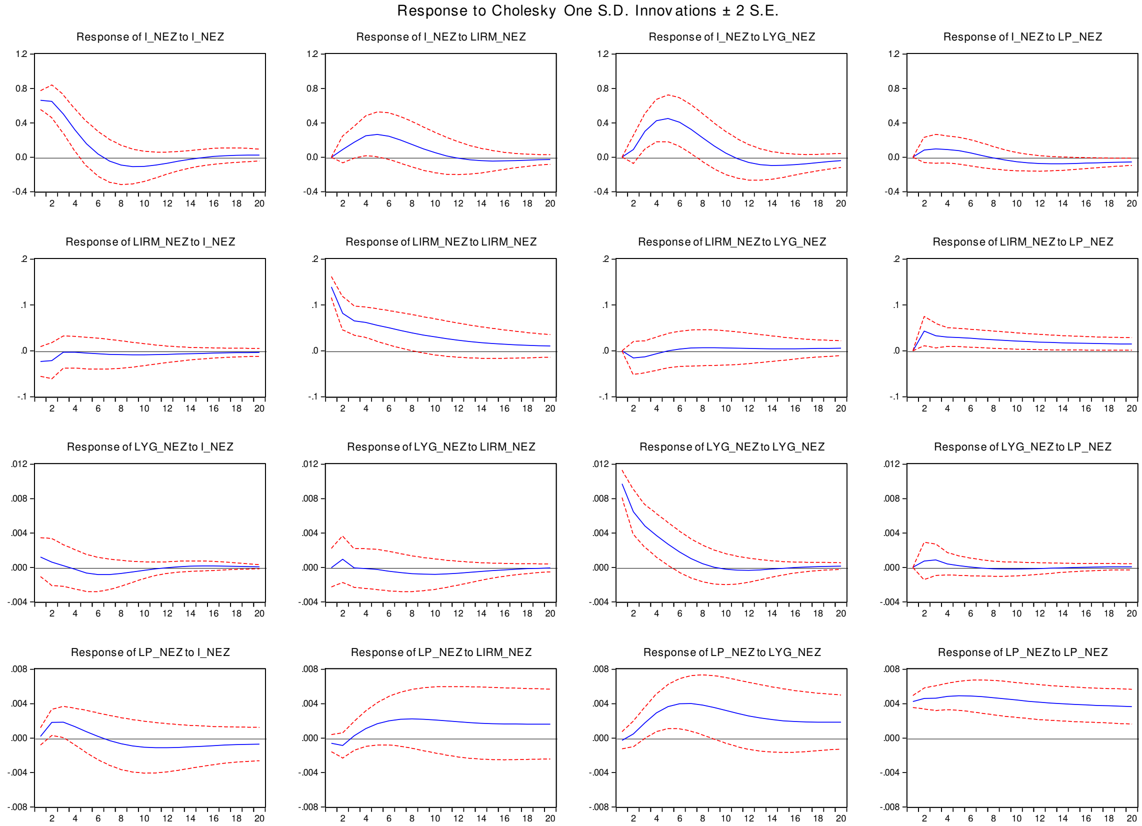
7.- VAR Korea


Response to Cholesky One S.D. Innovations ± 2 S.E.
Response of I_KOR to I_KOR
Response of I_KOR to LIRM_KOR
Response of I_KOR to LYG_KOR
Response of I_KOR to LP_KOR
Response of LIRM_KOR to I_KOR
Response of LIRM_KOR to LIRM_KOR
Response of LIRM_KOR to LYG_KOR
Response of LIRM_KOR to LP_KOR
Response of LYG_KOR to I_KOR
Response of LYG_KOR to LIRM_KOR
Response of LYG_KOR to LYG_KOR
Response of LYG_KOR to LP_KOR
Response of LP_KOR to I_KOR
Response of LP_KOR to LIRM_KOR
Response of LP_KOR to LYG_KOR
Response of LP_KOR to LP_KOR

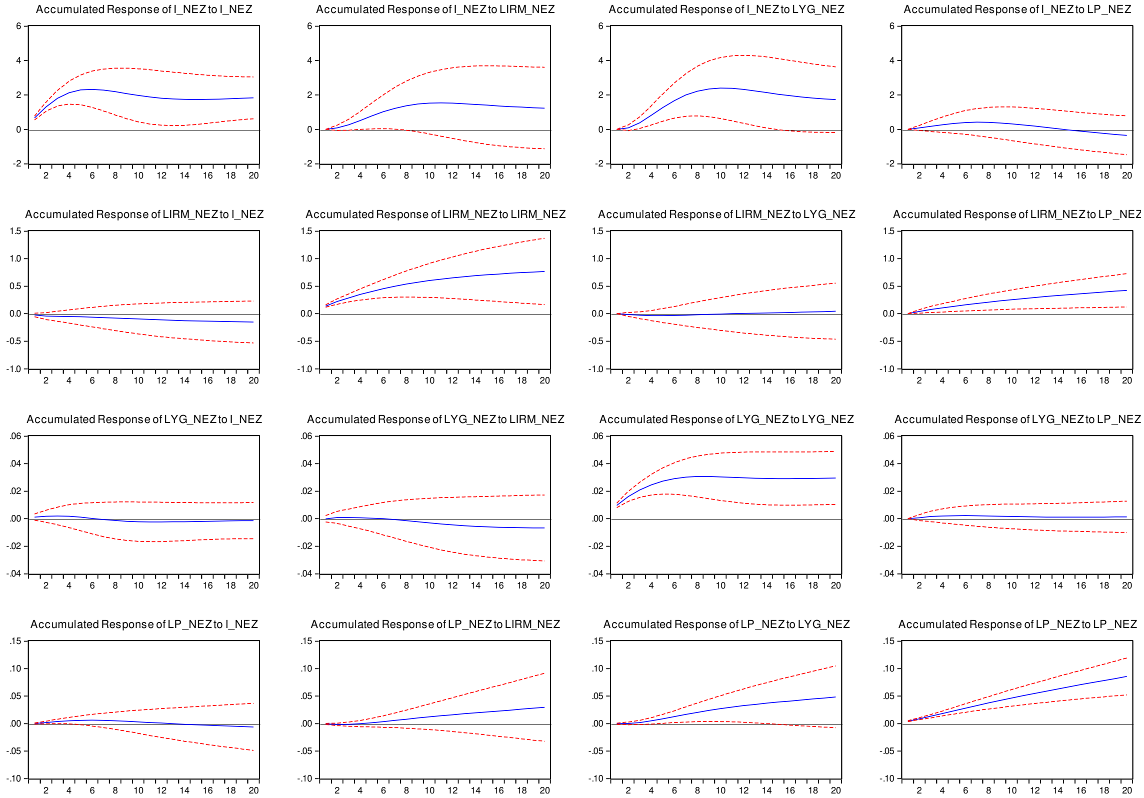
Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.



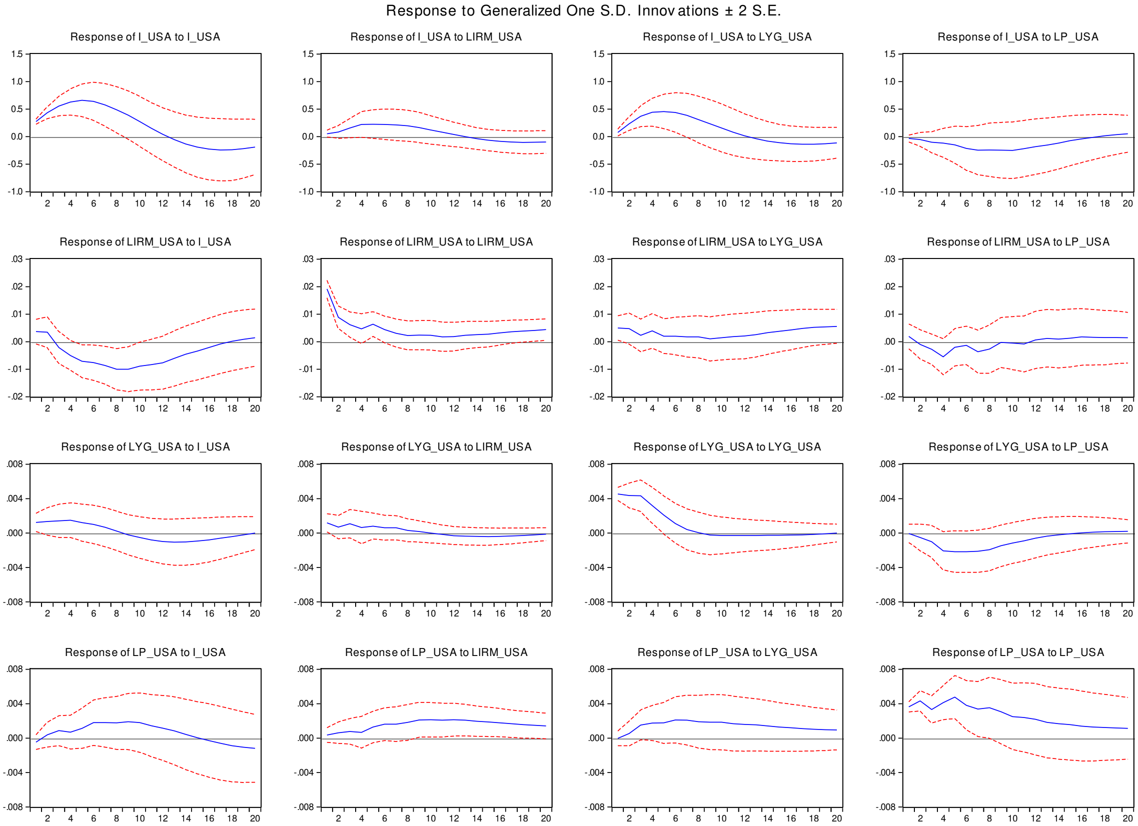
8.- VAR New Zealand



Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.



9.- VAR USA


Response to Generalized One S.D. Innovations ± 2 S.E.
Response of I_USA to I_USA
Response of I_USA to LIRM_USA
Response of I_USA to LYG_USA
Response of I_USA to LP_USA
Response of LIRM_USA to I_USA
Response of LIRM_USA to LIRM_USA
Response of LIRM_USA to LYG_USA
Response of LIRM_USA to LP_USA
Response of LYG_USA to I_USA
Response of LYG_USA to LIRM_USA
Response of LYG_USA to LYG_USA
Response of LYG_USA to LP_USA
Response of LP_USA to I_USA
Response of LP_USA to LIRM_USA
Response of LP_USA to LYG_USA
Response of LP_USA to LP_USA

Accumulated Response to Generalized One S.D. Innovations ± 2 S.E.