UNIVERSITY OF PIRAEUS

DEPARTMENT OF BANKING AND FINANCIAL MANAGEMENT

GRADUATE PROGRAM

MONETARY POLICY AND HOUSING PRICES

EVIDENCE FOR THE US, JAPAN AND CANADA

DIMITRIOS STRATIGOS

JUNE 2009

HOUSE PRICES AND MONETARY POLICY

DIMITRIOS STRATIGOS[1]

Abstract This paper explores both theoretically and empirically the links between house prices, equity prices , inflation, interest rates and economic activity, focusing mainly on the relationship between interest rates and real house prices, in three industrialized countries, namely the USA, Canada and Japan, over the last thirty years. In all three countries, Granger causality tests indicate that there is evidence of a significant bidirectional link between nominal short-term interest rates and the growth rate of real house prices. Analysis via impulse responses verified the expected cumulative response of the one variable to a shock in the other variable. Particularly after an interest rate shock, the growth rate of real house prices falls, with the duration of the effect varying from four quarters (USA) to twelve quarters (Canada). After a shock in the growth rate of real house prices, interest rates rise with the duration of the effect varying from six quarters (Canada) to eleven quarters (Japan). Finally, empirical evidence suggests that monetary authorities should be concentrated on targeting inflation and short run economic stability and that house prices should affect monetary policy only to the extent that they affect the inflation forecast of a central bank.

Keywords: house prices, monetary policy, wealth effect, collateral effect, Vector autoregressive model, Cholesky decomposition.

I. INTRODUCTION

In recent years many industrialized countries have experienced large increases in house prices triggered by low long-term real interest rates, ample credit and propitious economic conditions. In most countries a large boom in housing prices has been followed by a severe turmoil in the housing market subverting the stability of the financial system. This paper assesses the factors affecting the housing market, explores the various channels of the monetary policy transmission mechanism and focuses on how monetary policy should respond to booming house prices. Literature suggests that strong linkages exist between monetary policy[2], inflation, GDP, housing

[1] **Acknowledgements**: I would like to thank Mr Nikolaos Apergis for his useful comments and Mr Emmanouel Tsiritakis for his valuable moral support when I found myself in a very difficult situation. Also I would like to thank my mother Anna Vasiliou, my grandmother Eutixia Vasiliou and Elisavet Bosdelekidou for putting up with me during the completion of this paper. The views expressed in this paper are those of Dimitrios Stratigos and should not be interpreted as those of the University of Piraeus.

[2] Figure 1 illustrates the implementation of monetary policy in the Euro area to present the way that monetary authorities conduct their policy.

prices, equity prices and credit.[3] A common approach for inspecting the links between asset prices, interest rates and the macroeconomy has been the VAR approach. Goodhart and Hofmann (2008) used a panel vector autoregressive model for 17 countries spanning the period Q1 1973 – Q4 2006 and via the impulse responses function showed that a GDP shock causes the increase of real GDP, consumer prices, nominal interest rates, housing prices, money and credit. A house price shock triggers significant increases in all the variables, while an interest rate shock affects positively nominal interest rates and negatively the remaining variables. Finally a CPI shock causes the increase of CPI and nominal interest rates and the fall of real GDP and real house prices. Next they re-estimated the model for the period Q1 1985 – Q4 2006. The results of their analysis are interesting. First, the response of the CPI to a house price shock or a GDP shock or a CPI shock is much weaker, probably because after 1985, the implementation of monetary policy changed, targeting monetary stability. Second while the CPI fell after some time following an interest rate shock over the full sample, over the subsample it significantly increases. Goodhart and Hofmann interpret this as a more forward looking conduct of monetary policy since the mid 1980s. Finally they found that the effects of shocks to money and credit on housing prices are stronger when house prices are booming.[4] Tsatsaronis and Zhu (2004) found that the most important factor that drives house price variability is inflation. At the 5 year horizon inflation accounts for 53% of the total variation in house prices[5], while in the short run its effect is larger as at the 1 quarter horizon it accounts for 90% and at the 1 year horizon 65%. They also found that for those countries that use predominantly floating mortgage rates, the effect of short-term interest rates on house prices is much stronger, whereas for the countries that use predominantly fixed mortgage rates, the impact of the term spread on house prices is larger. Assenmacher-Wesche and Gerlach (2008) estimated a panel VAR for 17 countries, with a sample

---

[3] See Iacoviello (2000), Tsatsaronis and Zhu (2004), Goodhart and Hofmann (2008), Assenmacher-Wesche and Gerlach (2008).

[4] That means these 2 variables are valuable forecasting instruments of monetary authorities to prevent a prospective housing bubble.

[5] Second in importance and all equally important, credit, short-term interest rates and the term spread account for about one third of the observed variation of house prices. They found GDP as the least important factor, as it explains less than 10% of the total house price variation.

period spanning from 1986 to 2006, using the same endogenous variables as Goodhart and Hofmann did except for money, plus equity prices as an alternative investment. Impulse responses indicated that a shock in the growth rate of property prices causes the increase of equity prices with a peak after one quarter. Real GDP, credit and the interest rate peak after three to four quarters, whereas the CPI lags with a peak after ten quarters. An interest rate shock triggers a decrease in the price level approximately after 2 years. Real GDP falls and after 7 quarters starts to recover, credit falls after 3 quarters, house prices decrease gradually and reach a trough after 10 quarters, while equity prices start to fall immediately after the shock and start rising only after about seven quarters, that is, when real GDP starts to return to the initial level. In fact, the decrease of house prices after a rise in the nominal interest rate is 3 times bigger than the decrease of GDP, suggesting that in the sample period central banks did not seek to stabilize asset prices, but economic activity. Assenmacher-Wesche and Gerlach argue that if Central Banks were targeting equity and housing markets instead of monetary and economic stability, then a serious threat would be posed to GDP and inflation stability. Variance decomposition strengthens their argument. At a horizon of 6 years, interest rate shocks account for about 20% of the variation in the CPI and credit, and 28% of the fluctuations in GDP but only for 6% and 13% of the variation in property prices and equity prices respectively. Bernanke and Gertler (2001) suggest that monetary policy should have price stability as its primary objective and that changes in asset prices should affect monetary policy only to the extent that these changes affect the central bank's forecast of inflation. Monetary authorities should only react in the aftermath of the asset bubble, implementing an expansionary monetary policy in order to limit the damage to the economy. Mishkin (2001) has the same opinion and suggests that monetary policy should not target asset prices mainly for 3 reasons. First, it is very difficult for monetary authorities to identify that a bubble exists. Given that Central Banks have no informational advantage over the private sector, if a Central Bank already knows that a bubble has developed, then the market knows this also and would solve this problem on its own. Second, there is a great possibility that a Central Bank targeting asset prices may not achieve its goal and look incredible. Third it is possible that public may worry about the so many responsibilities of the Central Bank and its capability of affecting so many sectors of the economy. On the other hand Cecchetti, Genberg and Wadhwani (2002) argue that an inflation targeting central bank might improve macroeconomic performance by reacting to asset price misalignments over and above the extent that these changes affect the central bank's forecast of inflation.

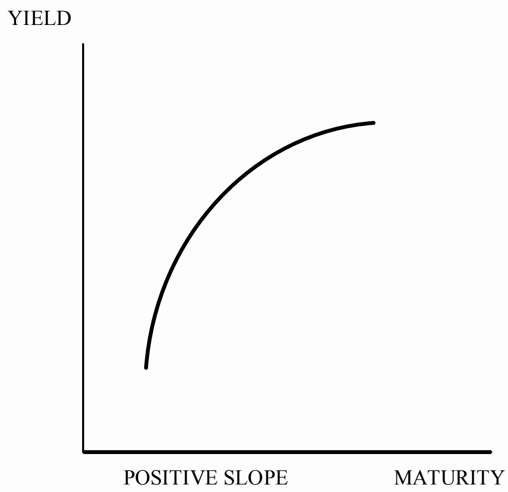
The accomplishment of price stability requires a great understanding of the transmission process of monetary policy and the various channels that it works through as well as its effects on output and inflation. In order to understand in depth the mechanism through which monetary policy implementation affects house prices and economic activity, we should first examine the link between short-term and long-term interest rates. Yield curve compares the yields on bonds with the same characteristics (risk, coupon rates etc) but different maturities. It plots the yields on bonds of different maturities against their maturities. 3 theories explain the shape of the yield curve. These are the unbiased expectations theory, the liquidity premium theory and market segmentation theory.[6] *The unbiased expectations theory* suggests that long-term interest rates are a function of current and expected future short-term interest rates that are set by monetary authorities. More specifically it argues that long-term rates are a geometric average of current and expected short-term rates. According to that theory, an investor that has a T-year horizon can either buy a zero coupon bond with a maturity of T years and yield to maturity R_{1T}, or can buy T successive 1-year zero coupon bonds.[7] The yield on the investment in the first annual bond is r_{11}, the yield of the investment in the second annual bond is r_{21} etc. However it is evident that the only annual yield investors are certain about today is r_{11} and is impossible for them to know exactly the prospective annual yields, for which they are generating estimates. The estimates for the future yields r_{21} and r_{31} are $E(r_{21})$ and $E(r_{31})$ respectively. In equilibrium, the return to holding a T-year bond to maturity should equal the expected return to investing in T successive one-year bonds. The following equation represents this relationship.

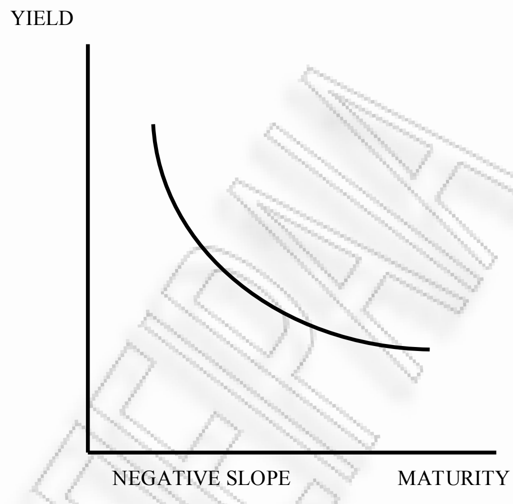
---

[6] Market segmentation theory suggests that investors' different maturity preferences affect the shape of the yield curve.

[7] We can estimate yields on zero coupon bonds from yields on par bonds, if we consider the last as a portfolio consisting of zero coupon bonds. If for example we have a par bond with a maturity of one year, coupon rate 7% and face value 100€ and a second par bond maturing in two years with coupon rate 8% and face value 100€, we can directly infer the return on a zero coupon bond maturing in two years. We split the flows of the two-year bond into 8€ the first year and 108€ the second year. Hence $100 = 8/1{,}07 + 108/(1+R_{12})^2$. We find that the two-year bond interest rate of the same face value is 8,04%.

$(1+R_{1T})^T = (1+r_{11}) \times (1+E(r_{21})) \times (1+E(r_{31})) \times \ldots\ldots\ldots\ldots \times (1+E(r_{T1}))$. (equation 1)[8]





According to equation 1 if expected future short-term rates rise each year into the future, then the yield curve will have an upward slope. If for example the market expects that ECB targeting inflation will conduct contractionary monetary policy into the future, then the yields of long-term bonds will be a positive function of their maturities. If the market participants expect that ECB will keep future interest rates constant into the future, the yields of long-term bonds will be the same with the yields of short-term bonds and the yield curve will remain constant. In that case the yield curve will be a straight line beginning from the yield axis and moving parallel to the maturity axis.

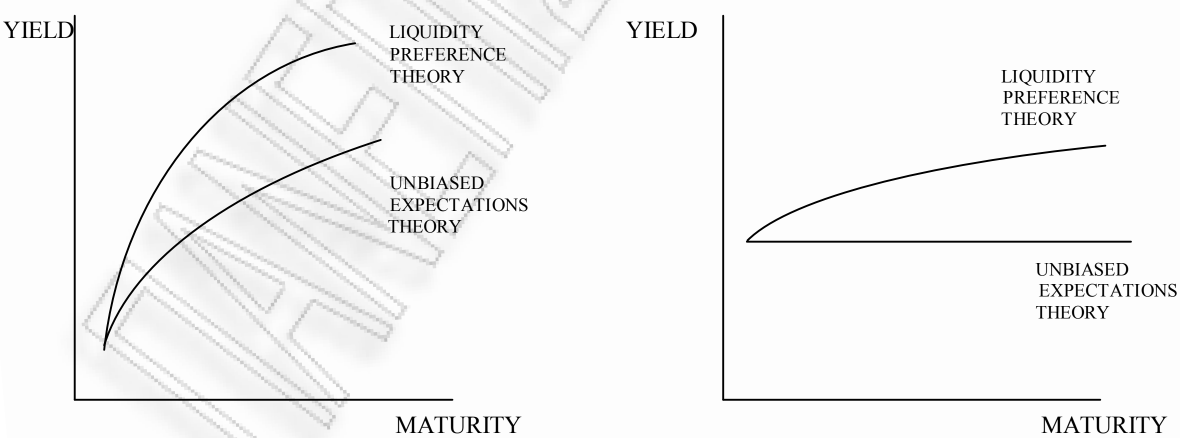
A great shortcoming of the theory is that according to what it argues and given that yield curve usually has an upward slope, investors always believe that future short-term rates will rise continuously into the future. In other words they believe that the future inflation will rise over and over into the future. In fact forward rates are not perfect predictors of future short-term rates and there is a great degree of uncertainty among investors concerning the future returns on the securities as they cannot know

---

[8] If we suppose continuous compounding and P(t,T) is the price of a zero coupon bond at time t that matures in T-t years, then $P(t,T) = e^{-R(t,T)(T-t)}$. Also the forward rate at time t for T years is $f(t,T) = -\frac{\partial \log P(t,T)}{\partial T}$. Hence yield to maturity is R(t,T) = $\frac{\int_t^T f(t,S)dS}{T-t}$, indicating that long-term yield on a bond is the average of the expected future short-term interest rates.

exactly the future monetary policy actions and the rate of the future inflation. An investor holding a long-term bond is largely dependent on the future inflation rate and the prospective conduct of monetary policy. A contractionary monetary policy causes an increase of the returns in the securities market and the only way the investor can sell the bond to acquire the requisite funds is to accept a lower price. The liquidity premium theory incorporates this future uncertainty and states that investors will hold long-term bonds only if they are offered a premium to compensate for the future uncertainty about the returns on their investment. The premium is a positive function of maturity, because the risk in holding long-term bonds increases with the maturity of the bonds. Equation 1 according to the second theory is represented as

$(1 + R_{1T})^T = (1 + r_{11}) \times (1 + E(r_{21}) + pr_2) \times (1 + E(r_{31}) + pr_3) \times \ldots\ldots\ldots \times (1 + E(r_{T1}) + pr_T)$. (equation2). According to the liquidity premium theory , an upward yield curve suggests that investors expect future short-term interest rates to rise, remain constant or decrease by analogy with the slope of the yield curve (term spread)[9]. A yield curve with a large term spread anticipates the rise of future short-term interest rates due to the increasing expected inflation. A yield curve with a small term spread is not clear if it heralds a rise of future rates, because the positive slope is attributed to the increasing liquidity premium. Thus future short-term rates are expected to be constant. Finally a downward sloped yield curve suggests that the market participants expect the prospective fall of short-term rates. (Because of a possible recession that calls for an expansionary monetary policy)



FUTURE INTEREST RATES ARE EXPECTED TO RISE

FUTURE INTEREST RATES ARE EXPECTED TO REMAIN CONSTANT

[9] The slope of the yield curve (term spread) is defined as the difference between the yield on the ten-year government bond and the yield on the 3-month government bond.

After examining the relationship between short-term and long-term interest rates we can easily understand that a contracted monetary policy or an expected future interest rate rise results in increasing long-term interest rates and rising borrowing costs. Firms cut back on their investment expenditures while households reduce the prospective purchases of dwellings, automobiles and other durable goods that can be financed with credit. The declining demand induces the fall of their price.[10] The housing price is equal to the discounted future net flows of the property holding (rents after expenses) and thus increasing interest rates drain the current and future economic activity, depressing house prices as the discount rate rises and expected future income inflows decrease.

Housing and equities are the greatest portfolio components of households in developed countries. Given that they are competing investments, a rise in equity prices brings about higher capital yields on equity holdings and thus higher returns in the market for equities deterring individuals from investing in the housing market. As a result the two asset prices should move in opposite directions (substitution effect). Besides this substitution effect that drives equity prices to move in the opposite direction from house prices, there are also three counterbalancing forces that drive the two asset prices in the same direction. These are a) the wealth effect on both markets, b) the forecasting capability of asset prices for the prospective economic activity and c) the household estimates of the probability of facing financial distress. A rise in either of the two asset prices affects positively the household wealth, which in turn affects the demand for both markets. Consequently, house and equity prices tend to move in the same direction. A rise in equity prices anticipates augmented future economic activity and thus higher future income (rents) for the property owners. Accordingly, investors turn to the housing market, driving house prices upwards. If investors estimate a high probability of facing financial distress due to an unpredictable income change, they can not easily sell consumer durables or immovable properties to satisfy their liquidity needs. Kearl and Mishkin (1977) found that as the stock of debt relative to financial assets increases, households are more likely to experience financial distress and thus lower their demand for illiquid assets, such as housing. On the contrary, if they hold more liquid assets (deposits, stocks, bonds), they can easily sell those assets and obtain the required liquidity. An

[10] Contrary, an expansionary monetary policy leads to falling nominal interest rates, which in turn generate increases in asset prices.

expansionary monetary policy leads to increasing equity prices and rising financial wealth. As a result households do not fear for their solvency and start purchasing durable goods and housing. Mishkin (1976) argued that easy past monetary policy affects the cost and availability of credit, thus inflicting a substantial increase in consumers' debt holdings relative to financial asset holdings and hence consumers reduce consumer durable expenditure. Depending on the relative importance of the divergent effects, the interaction between the two markets may be very different. Borio and McGuire (2004) for the period 1970 to 1999, showed that a peak in equity prices heralded a subsequent peak in house prices approximately after 2years. Further more they found evidence that short-term nominal interest rates were the most important factor affecting the lag length. Reductions in interest rates following a peak in equity prices lengthen the lag, while increases shorten it.[11]In particular, a 25 b.p. reduction in interest rates is associated with the increase of the lag length by about one quarter. In this way, they managed to explain the fact that four years after the global turmoil in equity markets in the second quarter of 1999 and despite the fall of economic activity after the crunch, house prices continued to rise in many countries until the second quarter of 2003.

The movements in asset prices could affect aggregate demand and economic activity in various ways. Rising asset prices can significantly affect real economic activity through their effect on consumption and private investment. The first channel is well explained from Tobin (1969). His theory focuses on the way which asset prices affect private investment. Tobin suggested that the ratio of the market value of the firm to the replacement cost of capital (Tobin's q) is a good indicator of a company's incentive to finance an investment issuing new stocks. If Tobin's q is greater than unity, which means the market value of the company is greater than the total value of its assets and thus its stock is overvalued, it would be profitable for the company to expand its investment only with a small issue of stocks. That triggers a considerable increase of investment and aggregate demand. Where housing is concerned, as house prices relative to the construction costs (Tobin's q about residential investment) increase, it is profitable for property developers to construct new houses as they can be sold above their construction cost. On the other hand, a Tobin's *q* ratio of less than unity implies that it is not profitable to construct new

---

[11] Zhu (2003) came to the same conclusions.

houses and residential investment will therefore fall. In the long run the augmented supply inflicts a decline in house prices and the Tobin's q converges on unity.

A second channel through which asset prices affect investment is the firm balance-sheet effects. Inasmuch as asymmetric information problems exist in credit markets, the capability of firms to borrow is greatly affected by the value of the collateral they can provide for credit institutions. Rising asset prices induce higher net worth of business firms which in turn means that there is more collateral for the loans made to a firm. Firms ameliorate their access to the credit markets and can borrow funds to finance business investment easier and at lower interest rates[12].

The third channel through which asset prices may have an impact on economic activity may arise via housing and equity wealth effects on consumption. Milton Friedman (1957) in order to explain the consuming behavior, made the permanent income hypothesis. He disunited current income in permanent and transitory income. Permanent income is the part of current income that individuals expect to earn during their life, while transitory income is the remainder of current income and is not expected to exist in future incomes. According to Friedman, consumption depends only on permanent income and not on transitory income. Consumers save the part of the transitory income to transfer it to future uncertain periods. Modigliani and Ando (1963), argued that income undergoes considerable fluctuations during the human life and that is because after some age most people retire. Individuals expect that above the age of retirement their income will be much lower than their income in the pre-retirement phase and in order to maximize lifetime utility from consumption and preserve their living standards given that they are subject to an intertemporal budget constraint, they will spend evenly over their life times, borrowing early in life when income is low relative to the average lifetime income, saving during their working lives and dissaving after their retirement. Hence, a combination of these two theories suggests that a permanent increase in asset prices carrying along a permanent increase in wealth and income, leads to increasing household spending and declining saving, as

[12] Bernanke, Gertler and Gilchrist (1996) suggest that a powerful financial accelerator effect exists in the economy. A fall in the borrower's net worth that reduces the collateral he can post, amplifies the initial macroeconomic shock, worsening further the private investment and economic activity as credit institutions curtail lending.

consumers want to allocate evenly the wealth gain over the rest of their lives[13]. Particularly, housing wealth effects on consumption should be larger than financial wealth effects on consumption, mainly for two reasons. First an increase in house prices is considered more permanent than an increase in equity prices, as the latter are more volatile. Hence, it is apparent that marginal propensity to consume out of housing wealth should be larger than the marginal propensity to consume out of financial wealth. Second, housing wealth is much more evenly distributed over the population than financial wealth. Given that the rich have lower marginal propensity to consume out of wealth, house price increases should have a larger effect on consumption than equity price increases.[14] Apart from wealth effects on consumption, there is also a collateral effect, as asymmetric information problems force credit institutions to demand collateral in order to provide credit. Higher asset prices ensure there is more collateral for the loans made to households and thus banks offer more credit and at lower interest rates. This paper empirically explores the role of the housing markets in the transmission mechanism of monetary policy in three of the G7 countries, namely the US, Canada and Japan. The remainder of the paper is organized as follows. Section 2 describes the data set. Section 3 describes the empirical methodology. Section 4 presents the empirical results and finally section 5 concludes.

II. DATA

The empirical analysis is based on quarterly data for the following 3 industrialized countries: the USA, Canada and Japan, for the period 1980Q1-2008Q4. Contrary to Goodhart and Hofmann (2008), I decided to include equity prices in the analysis as an alternative investment that influences the housing market. Also equity markets have undergone large swings as housing markets, so it is of great interest to observe the interaction between asset prices and monetary policy actions. The set of data series

[13] The impact of a permanent increase in house prices on consumption is not so clear as it is for equities. This is because landlords and homeowners will increase their consumption following a permanent increase in housing prices, but tenants who will have to pay higher rents and prospective buyers who will have to save more to satisfy the needs of their future purchase, will reduce their expenditures.

[14] For a more detailed comparison between housing and financial wealth effects on consumption, see Ludwig and Slok (2002), Case, Quigley and Shiller (2005).

used in the empirical analysis consists of the log difference of real GDP, the annual log difference of the consumer price index (CPI) named hereafter as inflation, the log difference of real house prices, the log difference of real equity prices and nominal short-term interest rates.

Real GDP and CPI data were taken from OECD Main Economic Indicators database. Short term rates were also taken from OECD Main Economic Indicators database. MEI data series are either the three month interbank offer rate attaching to loans given and taken amongst banks for any excess or shortage of liquidity over several months or the rate associated with Treasury bills, Certificates of Deposit or comparable instruments, each of three month maturity. A three-month CD rate was used for the US and Japan and a three-month prime corporate paper rate was used for Canada.

House price data were taken from DATASTREAM (US), CANSIM database (Canada) and Japan Real Estate Institute database (Japan). For Canada, the New Housing Price Index (NHPI) is a quarterly series that measures changes over time in the contractors' selling prices of new residential houses, where detailed specifications pertaining to each house remain the same between two consecutive periods. The survey also collects contractors' estimates of the current value (evaluated at market price) of the land. These estimates are independently indexed to provide the published series for land. The residual, (total selling price less land value), which mainly relates to the current cost of the structure is also independently indexed and is presented as the estimated house series. For the US, The Office of Federal Housing Enterprise Oversight (OFHEO) estimates and publishes quarterly house price indexes for single-family detached properties using data on conventional conforming mortgage transactions obtained from the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae). The HPI is produced using data on single-family detached properties financed by conforming conventional mortgages purchased by the enterprises. Thus, mortgage transactions on attached and multi-unit properties, properties financed by government insured loans, and properties financed by mortgages exceeding the conforming loan limits determining eligibility for purchase by Freddie Mac or Fannie Mae are excluded.[15] In Japan, according to Assenmacher-Wesche (2008), Goodhart and Hofmann (2008), a

[15] For more information about the OFHEO HOUSE PRICE INDEX see Calhoun (1996).

market for old homes practically does not exist as houses are normally torn down after a few decades. As a consequence, land prices determine the value of housing. However, only semi-annual data are available for the Residential land price index, so I use the Average Price per dwelling index of Tokyo Metro Area Condominium market as a proxy for housing prices. Figure 2 shows nominal house prices for the three countries spanning the period 1980Q1-2008Q4. The three economies experienced a sharp rise in residential property prices in the mid 1980s probably due to the deregulation and liberalisation of the mortgage markets which enhanced the households' access to mortgage credit. Japan faced a dramatic nominal house price deflation in the early 1990s coinciding with the collapse of the equity market. The collapse of the "bubble economy" in Japan brought about a ten-year recession period disrupting the good perspective of the Japanese economy until then. Canada faced a moderate house-price decline in the same period, following the US recession in 1990, while the US has not experienced a nominal house-price decline until the recent financial turmoil following the subprime mortgage loan crisis.

Equity prices were taken from OECD Main Economic Indicators database. For Canada, the S&P/TSX composite index of the Toronto Stock Exchange (formerly called the TSE 300 Composite index) measures the performance of the broad Canadian equity market. The index is a market capitalisation-weighted index. Monthly data are closing prices on the last trading day of the month. Quarterly data are averages of monthly figures. For US, the NYSE composite index of the New York Stock Exchange covers all listed companies on the New York Stock Exchange. Investment funds and foreign-registered companies are included. Monthly data are averages of daily quotations, quarterly data are averages of monthly figures. For Japan, the TOPIX index measures changes in the share prices of all companies listed in the First Section traded on the Tokyo Stock Exchange. The First Section comprises the largest companies of the Tokyo Stock Exchange. The First Section included close to 1500 companies in 2004. Investment funds are excluded. Monthly data are averages of daily quotations, quarterly data are averages of monthly figures. Figure 3 depicts equity prices for the three countries over the period 1980Q1-2008Q4. All countries experienced two large booms and busts from the mid 90's until today, with the letter M of the alphabet clear-cut shaped on the diagrams.

III. METHODOLOGY

To come to the empirical model, first I had to identify the order of integration of the series included in the analysis.[16] A series is stationary, only if $|\phi| < 1$ in the AR(1) process $y_t = \phi y_{t-1} + u_t$.[17] In the case where $\phi = 1$, the series is a random walk process, contains a unit root and is non-stationary. In this case if we take the first difference of the series Δy_t is a stationary series because it equals u_t which is a stationary white-noise process.[18] Dickey and Fuller (1979, 1981) suggested a unit root test that is useful to identify whether a time series is stationary or not. What they did was to subtract y_{t-1} from both sides of the AR(1) equation, obtaining $\Delta y_t = (\phi - 1) y_{t-1} + u_t = \delta y_{t-1} + u_t$. The null hypothesis of the Dickey-Fuller test is H_0: $\delta=0$ and the alternative hypothesis is H_1:$\delta<0$. If the null hypothesis is not rejected then the series y_t is a random walk process i.e. y_t has a unit root. If we reject the null hypothesis then y_t is I(0). The two alternative equations are $\Delta y_t = \gamma + \delta y_{t-1} + u_t$ and $\Delta y_t = \gamma + \varepsilon t + \delta y_{t-1} + u_t$. The first allows for a constant while the second allows for a constant and a deterministic time trend. These tests are credible only if the error term is a white noise process. However if the error term is not white noise then we have the problem of autocorrelation since the error term depends on its past values.

---

[16] A series is integrated of order 0 if it is stationary. If the series is not stationary we take the first difference of it and check if it is stationary. If yes, the series is integrated of order one. In general a non-stationary time series might need to be differenced more than once in order to become stationary. Thus the order of integration of the series equals the number of times the series needs to be differenced in order to become stationary.

[17] An AR(p) process can be written as $y_t(1 - \alpha_1 L - a_2 L^2 \cdots - a_p L^p) = u_t$ and is stationary if all the p roots of the polynomial equation Φ(L)=0 are greater than one in absolute value and $\sum_{i=1}^{p} a_i < 1$. It is obvious that in the case of the AR(1) process $yt(1 - aL) = ut \Rightarrow L = \frac{1}{a}$. In order to be a stationary process, $|L| = \left|\frac{1}{a}\right|$ must be greater than unity. That is equal to $|a| < 1$.

[18] Testing for Unit roots is important, because if all series are integrated of the same order, one should proceed with Cointegration and Error Correction Models to examine the long-run relations of the variables. Otherwise, differencing the series until obtaining stationarity is needed and Vector Autoregressive Models are the correct tool for analysis.

Dickey and Fuller extended the test creating the augmented Dickey-Fuller test for unit roots using κ extra lags of the dependent variable to cope with the problem of autocorrelation. Including extra lagged values of the dependent variable, the model becomes $\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{\kappa} \mu_i \Delta y_{t-i} + u_t$.[19] Figure 4 presents ADF unit root tests for the variables included in the analysis. All variables across countries are integrated of order one except for inflation that is integrated of order zero. Since I find that the series are not integrated of the same order I can not test for cointegration of the variables to explore the long-run relationships between them. Instead, I generate the first differences of I(1) variables to convert them to stationary series and the model I will proceed with is a multivariate vector autoregressive model.

When we have models of simultaneous equations where some variables explain other variables, but they are also explained by the variables that they are used to determine, we should not predetermine which variables are explanatory and which are endogenous. Sims (1980) suggested that if there is simultaneity among a number of variables, then all these variables should be treated symmetrically as endogenous and introduced vector autoregressive models into econometrics. A VAR is a system regression model in which k variables are treated as endogenous, each of whose current value is explained by its own lagged values, plus current and past values of the remaining k-1 variables. Consider for example the bivariate time series $z_t = \begin{pmatrix} y_t \\ x_t \end{pmatrix}$ that is a VAR process of first order.

$$y_t = \beta_{10} + \beta_{11} x_t + \gamma_{11} y_{t-1} + \gamma_{12} x_{t-1} + u_{yt}$$
$$x_t = \beta_{20} + \beta_{21} y_t + \gamma_{21} y_{t-1} + \gamma_{22} x_{t-1} + u_{xt}$$

where y_t and x_t are stationary and the vector $u_t = \begin{pmatrix} u_{yt} \\ u_{xt} \end{pmatrix}$ consists of uncorrelated white noise error terms. Such a VAR that allows for contemporaneous feedback terms is called a structural VAR and can be written in terms of matrix algebra as:

$$\begin{pmatrix} 1 & -\beta_{11} \\ -\beta_{21} & 1 \end{pmatrix} \begin{pmatrix} y_t \\ x_t \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix} \begin{pmatrix} y_{t-1} \\ x_{t-1} \end{pmatrix} + \begin{pmatrix} u_{yt} \\ u_{xt} \end{pmatrix} \quad \text{or} \quad \mathbf{B z_t = B_0 + \Gamma_1 z_{t-1} + u_t}$$

[19] Again the model can incorporate a constant or a constant and a non-stochastic time trend.

where $\mathbf{B} = \begin{pmatrix} 1 & -\beta_{11} \\ -\beta_{21} & 1 \end{pmatrix}$, $\mathbf{z_t} = \begin{pmatrix} y_t \\ x_t \end{pmatrix}$, $\mathbf{B_0} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix}$, $\mathbf{\Gamma_1} = \begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix}$, $\mathbf{z_{t-1}} = \begin{pmatrix} y_{t-1} \\ x_{t-1} \end{pmatrix}$, $\mathbf{u_t} = \begin{pmatrix} u_{yt} \\ u_{xt} \end{pmatrix}$

The existence of contemporaneous terms on the right-hand side of the equations does not allow us to estimate each equation by OLS, because in that case OLS yields biased and inconsistent estimators. However, if we multiply both sides by $\mathbf{B}^{-1}$ we have $\mathbf{z_t} = \mathbf{E_0} + \mathbf{E_1 z_{t-1}} + \mathbf{e_t}$, where $\mathbf{E_0} = \mathbf{B}^{-1}\mathbf{B_0}$, $\mathbf{E_1} = \mathbf{B}^{-1}\mathbf{\Gamma_1}$ and $\mathbf{e_t} = \mathbf{B}^{-1}\mathbf{u_t}$.

Now the model can be written as a VAR in reduced form and OLS can be used to estimate each equation separately.

$$y_t = \varepsilon_{10} + \varepsilon_{11} y_{t-1} + \varepsilon_{12} x_{t-1} + e_{yt}$$

$$x_t = \varepsilon_{20} + \varepsilon_{21} y_{t-1} + \varepsilon_{22} x_{t-1} + e_{xt}$$

where e_t comprises white noise error terms with mean zero and covariance matrix Σ [20], that may be contemporaneously correlated but are uncorrelated with their own lagged values.

VAR models have received severe criticism because they are not based on any economic theory as each variable in the system is treated as endogenous. However one can use Granger causality tests to identify the causing relationships between the variables and be consistent with economic theory. Granger (1969) suggested that a variable x is said to "Granger-cause" another variable y if y can be predicted more accurately by using past values of x rather than not using these past values. In the bivariate vector autoregressive model of order m,

$$y_t = a_{10} + \sum_{i=1}^{m} \beta_{1i} x_{t-i} + \sum_{j=1}^{m} \gamma_{1j} y_{t-j} + u_{1t}$$

$$x_t = a_{20} + \sum_{i=1}^{m} \beta_{2i} x_{t-i} + \sum_{j=1}^{m} \gamma_{2j} y_{t-j} + u_{2t}$$

where u_{1t} and u_{2t} are taken to be two uncorrelated white-noise series, y is said to Granger-cause x if all the lagged terms of y in the second equation are statistically significant and all the lagged terms of x in the first equation are not statistically different from zero. If all the lagged terms of x in the first equation are statistically significant but all lagged terms of y in the second equation are not significant, then x

[20] Σ must be a positive definite matrix, that is it must be symmetric and all its eigenvalues must be positive.

is said to Granger-cause y. If both sets of lags are significant, it would be said that there is bi-directional causality between the two variables and in the case where each variable can be predicted only by using its own past values, x is independent of y.

Since VARs are a-theoritic, the obtained coefficients of the VAR models are difficult to interpret. However analysis via impulse response functions and variance decomposition facilitates the identification of the presumptive dynamic relations between the variables. The impulse response function examines the response of current and future values of each of the variables to shocks in the current value of one of the errors assuming that all other errors are held constant. Variance decomposition examines how much of the variation in an endogenous variable is due to its own shocks and what portion is due to shocks to the other variables. Impulse responses and variance decomposition would have a great sense if the errors were uncorrelated across equations. However the errors of one equation are likely to be correlated with the errors of another equation, thus impulse response functions and variance decomposition are not computed for the errors of the reduced-form VAR.[21] To overcome that problem we have to orthogonalize the shocks using Cholesky decomposition. Orthogonalisation is a transformation which results in a set of new residuals e_t satisfying $E(e_t e_t') = I$. To identify the structural system exactly, we have to restrict one parameter of it, since it contains ten parameters while the reduced-form VAR contains only nine[22]. Given that the covariance matrix Σ is positive definite, there exists a lower triangular unit matrix **L** and a diagonal matrix ***G*** such that $\Sigma = LGL'$**.** Therefore $L^{-1}\Sigma(L')^{-1}$ must be a diagonal matrix. Multiplying L^{-1} to the reduced-form VAR matrix representation**,** one can obtain the structural equations**.** That method imposes $\frac{n \times (n-1)}{2}$ restrictions on the matrix that contains the contemporaneous terms, converting it in a lower triangular unit matrix. Therefore, in the preceding bivariate VAR example, matrix B is transformed as $\mathbf{B} = \begin{pmatrix} 1 & 0 \\ -\beta_{21} & 1 \end{pmatrix}$

21 If errors are correlated across equations, the response of a variable to a shock in one of the errors would not be clearly attributed only to that shock.

22 The structural model contains β_{10}, β_{20}, β_{11}, β_{21}, γ_{11}, γ_{21}, γ_{12}, γ_{22}, Var(u_y), Var(u_x), whereas the reduced-form model contains ε_{10}, ε_{20}, ε_{11}, ε_{21}, ε_{12}, ε_{22}, cov(e_y,e_x), Var(e_y), Var(e_x).

and $\mathbf{e_t} = \mathbf{B^{-1}} \mathbf{u_t} = \begin{pmatrix} 1 & 0 \\ \beta_{21} & 1 \end{pmatrix} \begin{pmatrix} u_{yt} \\ u_{xt} \end{pmatrix}$. Thus the residuals whose effects are being tracked, are the residuals from a system in which contemporaneous values of other variables enter the right-hand-sides of the regressions with a triangular array of coefficients. Hence, impulse responses functions and variance decomposition are computed for a triangular representation of the reduced-form error terms:

$$e_{yt} = u_{yt}$$
$$e_{xt} = \beta_{21} u_{yt} + u_{xt}$$

These restrictions imply an ordering of the variables that reflects potential contemporaneous effects. Hence, the first variable in the ordering may respond with a lag to innovations in the subsequent variables, but its innovations affect all the remaining variables within the same period. The ordering of the variables is of great importance, especially if the error terms are correlated across equations, thus one must be careful before ordering the variables as there is a great possibility that he will obtain meaningless results.

Returning to the purpose of this paper, the empirical analysis is based on three reduced-form vector autoregressive models, one for each country, given by: $\Theta_t = A_0 + A(L)\Theta_t + \varepsilon_t$, where Θ_t is a vector of endogenous variables comprising the log difference of real GDP (DlogRGDP), the level of the inflation rate defined as the annual changes of the log of the consumer price index (INF), the difference of the short-term nominal interest rate (DI), the log difference of real residential house prices (DlogRHP) and the log difference of real equity prices (DlogREP). The nominal interest rate is used to capture monetary policy shocks. The vector Θ_t is therefore given by $\Theta_t = [D\log RGDP, INF, DI, D\log RHP, D\log REP]'$. A_0 is a 5x1 vector of constant terms, A(L) is a matrix polynomial in the lag operator whose order is determined by the sequential modified LR test statistic separately for each country considering a maximum lag length of four[23], and ε_t is a vector of white-noise errors contemporaneously correlated with each other but serially uncorrelated. A problem I had to cope with was the loss of degrees of freedom. Sims (1980) argued that if every variable is allowed to influence every other variable with a distributed lag of

[23] Figure 5 presents the various information criteria for lag length selection of the VAR model.

reasonable length, without restriction, the number of parameters grows with the square of the number of variables and quickly exhausts degrees of freedom. If the sample size is relatively small, degrees of freedom will rapidly be used up, creating problems in estimation. This paper uses a relatively large sample size from 1980 Q1 to 2008 Q4 hence it effectively deals with that problem. In order to identify the orthogonalized shocks, I use a Cholesky decomposition. As previously mentioned the ordering of the variables is of great importance, especially if the correlation of the reduced-form errors is large. Fortunately, the ordering of the variables is highly suggested from the monetary transmission literature to be as above. Hence the growth rate of real GDP is ordered first because innovations in the growth rate of real GDP affect all the other variables within the same quarter. Inflation is ordered second, because it is assumed that innovations in the inflation rate affect interest rates and the real growth rate of housing and equity prices within the same quarter, but real GDP is affected with a lag. The interest rate responds immediately to a shock in real GDP or Inflation, but only with a lag to a shock in asset prices. Finally house prices were ordered before equity prices, because the price of a house is stickier than the price of a stock. In that way equity prices respond immediately to innovations in all the preceding variables. In the next section, I present the results of Granger causality tests, impulse response analysis and variance decomposition for each country, to assess the direction and strength of the dynamic relations between the variables.

IV. EMPIRICAL RESULTS

The vector autoregressive model described in the previous section was estimated for each of the three countries over the period 1980Q1-2008Q4, with a lag order of four, which was selected based on the sequential modified LR test statistic.[24]

[24] I chose the sequential modified LR test statistic rather than the other information criteria, because it indicated four lags, the only number of lags that the VAR model did not suffer from heteroskedasticity or autocorrelation. Figure 5 presents the various lag length criteria for Canada, while figure 6 presents the diagnostic tests of the residuals for Canada. For the US and Japan the sequential modified LR test statistic indicated four lags. VAR Lag Order Selection Criteria and diagnostic tests of the residuals for the US and Japan are available upon request.

CANADA

Table 1 presents the results from the Granger causality tests for Canada. At the 5% significance level, real GDP growth is found to have a significant direct effect on future inflation and future interest rates, a significant bidirectional causality exists between inflation and house price inflation, asset price inflation significantly affects the future interest rates, while only equity price inflation affects the future growth of real GDP. At the 10% significance level, interest rates directly affect the future growth of real GDP, the future inflation and the future house price inflation and house price inflation significantly affects the future equity price inflation.

TABLE 1 ***GRANGER CAUSALITY TESTS CANADA***

DlogRGDP ⟶ INF **2.82635*** **(0.02882)**	**DlogRGDP ⟶ DI** **11.1618*** **(1.7E-07)**	DlogRGDP ⟶ DlogRHP 0.40592 (0.80399)	DlogRGDP ⟶ DlogREP 0.50346 (0.73325)
INF ⟶ DlogRGDP 0.76521 (0.55040)	INF ⟶ DI 1.84419 (0.12638)	**INF ⟶ DlogRHP** **2.70445*** **(0.03471)**	INF ⟶ DlogREP 0.57989 (0.67790)
DI ⟶ DlogRGDP **2.05920**** **(0.09199)**	**DI ⟶ INF** **2.31354**** **(0.06274)**	**DI ⟶ DlogRHP** **2.07672**** **(0.08962)**	DI ⟶ DlogREP 0.21592 (0.92902)
DlogRHP ⟶ DlogRGDP 1.22114 (0.30682)	**DlogRHP ⟶ INF** **7.70722*** **(1.9E-05)**	**DlogRHP ⟶ DI** **4.31577*** **(0.00294)**	**DlogRHP ⟶ DlogREP** **2.32532**** **(0.06172)**
DlogREP ⟶D logRGDP **2.57434*** **(0.04232)**	DlogREP ⟶ INF 0.65336 (0.62588)	**DlogREP ⟶ DI** **4.02168*** **(0.00461)**	DlogREP ⟶ DlogRHP 0.89330 (0.47105)

The table reports F-statistics for Granger causality tests. P-values are in parentheses. * denotes significant test statistics at the 5% significance level, while**denotes significant test statistics at the 10% significance level. Significant test statistics are in bold.

Although Granger causality tests provide us with great information about the direct relationships between the endogenous variables of the model, they do not take into account the indirect effects coming from the remaining variables of the system and the direction of these effects. Given that most effects between macroeconomic variables are indirect via other variables, next I perform an impulse response analysis to assess better the dynamic interrelationships between the variables. Figure 7 displays the impulse responses of the five variables to orthogonalized one S.D. innovations in a two-standard-error confidence band for the country of Canada. A GDP growth shock has a positive influence on GDP growth that leaves off six quarters after the initial shock. Inflation increases four quarters after the shock with the effect gradually diminishing while the interest rate rises for seven quarters and thereafter remains unresponsive to the shock. Asset prices respond slightly to a GDP growth shock, with the growth rate of real house prices rising for seven quarters and the growth rate of real equity prices rising for three quarters after the initial shock. An inflation shock brings about a decline in the growth rate of real GDP for about six quarters and a substantial rise in the inflation rate that continues to exist even after fifteen quarters. The growth rate of real housing prices falls immediately after the shock, then rises for three quarters and then falls again for twelve consecutive quarters. The responses of the interest rate and the growth rate of real equity prices are statistically insignificant. An interest rate shock triggers a decline in the growth rate of real GDP that lasts for two years. Inflation rises for seven quarters before starting to fall for thirteen consecutive quarters. This phenomenon of an initial positive response of the inflation rate to an interest rate increase is known as the price puzzle and can be explained mainly by two factors. First, after an interest-rate increase, firms face augmented borrowing costs and as a result have an incentive to increase the prices of their products to offset the rising costs. Second the price puzzle may arise via misspecification of the empirical model. VAR models are dynamic models that use only present and past information of the endogenous variables and thus ignore any prospective information that could enter the information set. Given that the implementation of monetary policy has been strictly forward-looking since the mid-1980s, valuable systematic information joins the unsystematic part of the interest-rate equation, so that the impulse response includes the reaction of monetary authorities to the expected future inflation. Interest rates rise temporarily for two quarters and then fall for nine quarters while the growth rate of real housing prices falls for twelve quarters after the interest-rate shock and the cumulative response of the growth rate of real equity prices is negative and dies out after fifteen quarters. A shock in the growth rate of real housing prices drives positively the growth rate of real GDP for six quarters. Inflation decreases after a lag for about six quarters and then rises for eleven quarters. Interest rates rise after two quarters until eight quarters after the initial shock. The growth rate of real housing prices responds positively, immediately after the shock, for 10 quarters while the growth rate of real equity prices rises for three quarters, and after the fourth quarter falls until the ninth quarter. An equity-price growth shock inflicts an increase in the growth rate of real GDP for five quarters, an inflation increase after seven quarters and an interest-rate increase for seven quarters. The growth rate of real house prices rises for six quarters while the growth rate of real equity prices rises for four quarters after the shock.

Figure 8 shows the variance decomposition of the variables included in the VAR model for the country of Canada. As one would expect, the proportion of the variance of a variable due to its own shock is greater than the proportion of the variance due to a shock in another variable, and that percent decreases over time while the percent of the variance that is attributed to other shocks grows over time. At the two-quarter horizon, shocks in the growth rate of real GDP account for 93% of the variation in the growth rate of real GDP, while at a horizon of five quarters GDP growth shocks account for 78% of the variation in real GDP growth. Interest–rate shocks explain 9% and shocks in the growth rate of real equity prices are responsible for 7%.

At the two-quarter horizon shocks in the inflation rate account for 98% of its own variation while at the five-quarter horizon the inflation variation is explained 90% by its own shocks, 6% by shocks in the growth rate of real house prices and 2% by the growth rate of real GDP. At a horizon of ten quarters inflation is 79% contingent on its own shocks, 10% on shocks in the growth rate of real house prices and 7% on shocks in the growth rate of real GDP. Interest rate variation is 86% due to its own shocks and 14% due to shocks in the growth rate of real GDP at the two-quarter horizon, while it is 63% due to its own shocks, 21% due to shocks in the growth rate of real GDP, 8% due to the growth rate of real house prices and 7% due to shocks in the growth rate of real equity prices at the five-quarter horizon.

Turning to the variation of the growth rate of real house prices, own shocks are responsible for 83%, the interest rate has no explanatory power and inflation accounts for 12% of it at the one-quarter horizon. At the ten-quarter horizon, own shocks account for 67% of the variation, while the interest rate is the second most staple factor accounting for almost 1/5 of the variation in the growth rate of real house prices. Finally, interest rates and the growth rate of real GDP together explain 10% of the variation of the growth rate of real equity prices at the one-quarter horizon, with the rest being explained by own shocks, while at a horizon of ten quarters own shocks account for 77% of the variation, followed by shocks in the growth rate of real house prices that are responsible for 8% of the variation in the growth rate of real equity prices.

USA

TABLE 2 ***GRANGER CAUSALITY TESTS US***

DlogRGDP → INF **3.05305*** **(0.02057)**	**DlogRGDP → DI** **3.80038*** **(0.00657)**	DlogRGDP → DlogRHP 0.04005 (0.99690)	DlogRGDP → DlogREP 0.18484 (0.94576)
INF → DlogRGDP **6.75101*** **(8.0E-05)**	**INF → DI** **3.27414*** **(0.01468)**	INF → DlogRHP 0.64029 (0.63507)	INF → DlogREP 0.90034 (0.46711)
DI → DlogRGDP **8.20170*** **(1.0E-05)**	**DI → INF** **5.35293*** **(0.00063)**	**DI → DlogRHP** **2.01205**** **(0.09905)**	DI → DlogREP 0.24794 (0.91025)
DlogRHP → DlogRGDP **3.36946*** **(0.01269)**	**DlogRHP → INF** **7.45392*** **(2.9E-05)**	**DlogRHP → DI** **2.78563*** **(0.03092)**	DlogRHP → DlogREP 1.42796 (0.23079)
DlogREP → D logRGDP **4.42496*** **(0.00254)**	**DlogREP → INF** **2.85286*** **(0.02791)**	**DlogREP → DI** **2.21263**** **(0.07347)**	DlogREP → DlogRHP 0.71313 (0.58499)

The table reports F-statistics for Granger causality tests. P-values are in parentheses. * denotes significant test statistics at the 5% significance level, while**denotes significant test statistics at the 10% significance level. Significant test statistics are in bold.

Table 2 presents the results from the Granger causality tests for the US. At the 5% significance level, the growth rate of real GDP is found to have a significant direct effect on future inflation and future interest rates, inflation is found to have a significant impact on the future growth of real GDP and future interest rates, nominal interest rates directly affect the future growth of real GDP and future inflation, while the growth rate of real house prices has a significant effect on future growth rate of real GDP, inflation and interest rates. Finally, the growth rate of real equity prices is found to affect the future growth rate of real GDP and the future inflation rate. At the

10% significance level, interest rates directly affect the future growth rate of real house prices and the growth rate of real equity prices directly affects future interest rates.

Figure 9 displays the impulse responses of the five variables to orthogonalized one S.D. innovations in a two-standard-error confidence band for the USA. A shock in the growth rate of real GDP inflicts an immediate increase in the growth rate of real GDP that lasts for five quarters and an increase in the inflation rate that lasts approximately fifteen quarters. Interest rates rise immediately after the shock for six quarters and then fall for six quarters before the effect dies out. The response of asset prices to the shock is negative, with the reaction of the growth rate of real house prices stopping after eighteen quarters and the reaction of the growth rate of real equity prices stopping after nine quarters.

After an inflation shock, the growth rate of real GDP falls for nine quarters, inflation rises for 12 quarters, interest rates rise temporarily before they start falling for eight quarters and the growth rates of asset prices respond negatively to the shock with the response of the growth rate of house prices being much more prolonged than the response of the growth rate of equity prices. A monetary policy shock leads to a fall in the growth rate of real GDP after the second quarter that lasts for five quarters. Inflation rises for five quarters and then decreases for nine quarters verifying the price puzzle that existed in the analysis for Canada. Interest rates rise temporarily, while the growth rate of real house prices and the growth rate of real equity prices fall for four and three quarters respectively.

A shock in the growth rate of real house prices is associated with a fall in the growth rate of real GDP, a lasting positive response of the inflation rate, a rise in interest rates and a considerable increase in the growth rate of real house prices. Finally, the growth rate of real equity prices has an initial positive response which turns into negative three quarters after the shock and lasts for seven quarters. A shock in the growth rate of real equity prices leads to an increase in the growth rate of real GDP that lasts for five quarters, an increase in the inflation rate for fifteen quarters, a rise in interest rates for five quarters, a fall in the growth rate of real house prices after a year that lasts nine quarters and a temporary rise in the growth rate of real equity prices that lasts approximately three quarters.

Figure 10 shows the variance decomposition of the variables included in the VAR model for the country of USA. At a horizon of two quarters, the proportion of the variance of the growth rate of real GDP is 89% due to its own shock and 8% due to a shock in the growth rate of real equity prices. At the ten-quarter horizon, the growth rate of real GDP is the most salient factor (67%) followed by the growth rate of real equity prices (12%), interest rates (10%) and inflation (8%).

At the two-quarter horizon, shocks in the inflation rate account for 95% of its own variation while at the ten-quarter horizon the inflation variation is explained 69% by its own shocks, 10% by the growth rate of real equity prices, 9% by nominal interest rates and 8% by the growth rate of real GDP. Interest rate variation is 90% due to its own shocks and 7% due to shocks in the growth rate of real asset prices at the two-quarter horizon, while it is 73% due to its own shocks, 9% due to shocks in the growth rate of real GDP, 8% due to the inflation rate and 6% due to shocks in the growth rate of real equity prices at the ten-quarter horizon.

Regarding the variation in the growth rate of real house prices, own shocks account for 69% and inflation for 27% at the one-quarter horizon. At the ten-quarter horizon, own shocks account for 55%, inflation for 28% and interest rates for 11%. Variation in the growth rate of real equity prices is explained 76% by own shocks, 10% by shocks in the inflation rate, 7% by interest rate shocks and 6% by shocks in the growth rate of real house prices at a horizon of ten quarters.

<u>JAPAN</u>

Table 3 presents the results from the Granger causality tests for Japan. At the 5% significance level, interest rates are found to have a significant direct impact on the future growth rate of real equity prices and the future growth rate of real house prices, the growth rate of real house prices is found to have a significant effect on future interest rates, interest rates directly affect the future inflation rate, the growth rate of real equity prices is found to have a direct impact on the future growth rate of real house prices and on the future growth rate of real GDP, while the growth rate of real GDP has a direct effect on the future inflation rate.

TABLE 3 *GRANGER CAUSALITY TESTS JAPAN*

DlogRGDP ⟶ INF **4.88423*** **(0.00124)**	DlogRGDP ⟶ DI 0.40100 (0.80751)	DlogRGDP ⟶ DlogRHP 0.59772 (0.66514)	DlogRGDP ⟶ DlogREP 1.37300 (0.24887)
INF ⟶ DlogRGDP 1.50386 (0.20697)	INF ⟶ DI 1.38571 (0.24441)	INF ⟶ DlogRHP 1.39378 (0.24175)	INF ⟶ DlogREP 0.78139 (0.53993)
DI ⟶ DlogRGDP 0.83278 (0.50752)	**DI ⟶ INF** **2.72917*** **(0.03337)**	**DI ⟶ DlogRHP** **2.86353*** **(0.02821)**	**DI ⟶ DlogREP** **2.79574*** **(0.03020)**
DlogRHP ⟶ DlogRGDP 1.07543 (0.37290)	DlogRHP ⟶ INF 0.90581 (0.46375)	**DlogRHP ⟶ DI** **2.56130*** **(0.04317)**	DlogRHP ⟶ DlogREP 1.11306 (0.35480)
DlogREP ⟶D logRGDP **2.87676*** **(0.02668)**	DlogREP ⟶ INF 0.22337 (0.92478)	DlogREP ⟶ DI 0.85495 (0.49394)	**DlogREP ⟶ DlogRHP** **2.89591*** **(0.02591)**

The table reports F-statistics for Granger causality tests. P-values are in parentheses. * denotes significant test statistics at the 5% significance level, while**denotes significant test statistics at the 10% significance level. Significant test statistics are in bold.

Figure 11 displays the impulse responses of the five variables to orthogonalized one S.D. innovations in a two-standard-error confidence band for Japan. As expected, a shock in the growth rate of real GDP leads to a positive cumulative response of the growth rate of real GDP, a prolonged positive response of the inflation rate and positive cumulated responses of the nominal interest rate and the growth rate of real asset prices. An inflation shock has a positive effect on the inflation rate, interest rates rise for four quarters and then fall for ten quarters, the growth rate of real house prices rises initially for three quarters and then falls for eight quarters, while the growth rate of real equity prices falls for seven quarters. The cumulative response of the growth rate of real GDP to an inflation shock is negative as expected . An interest rate shock inflicts a negative cumulative response of the growth rate of real GDP. The price puzzle exists again as in USA and Canada, with the inflation rate rising for nine quarters after the monetary policy shock, before it starts falling. Interest rates rise for six quarters and then fall for nine quarters, while the growth rates of real asset prices have the expected negative cumulative responses. A shock in the growth rate of real house prices leads to a rise in the growth rate of real GDP that lasts for eleven quarters. Inflation falls after a lag for five quarters and then rises for fifteen quarters, interest rates rise for eleven quarters, the cumulative response of the growth rate of real house prices is positive while the cumulative response of the growth rate of real equity prices is slightly positive. Finally a shock in the growth rate of real equity prices triggers significant increases in all the variables.

Figure 12 shows the variance decomposition of the variables included in the VAR model for Japan. At a horizon of two quarters, the proportion of the variance of the growth rate of real GDP is 95% due to its own shock while at the ten-quarter horizon, the growth rate of real GDP is the most salient factor (69%) followed by the growth rate of real equity prices (14%), the growth rate of real house prices (8%) and interest rates (5%). The proportion of the variance of the inflation rate due to its own shocks is 93% at the two-quarter horizon, while it is 53% at the ten-quarter horizon followed by shocks in the growth rate of real GDP (35%). At the ten-quarter horizon interest rate variation is primarily affected by own shocks (78%), with the rest variables accounting equally for the rest 22%. Regarding the variation in the growth rate of real house prices, own shocks account for 77%, followed by shocks in the growth rate of real equity prices (10%) and shocks in interest rates (5%). Finally variation in the growth rate of real equity prices is 73% due to own shocks, 11% due to shocks in interest rates and 8% due to shocks in the growth rate of real GDP.

I also test the robustness of the individual country models and the reliability of the findings by changing the ordering of the variables in the models. More precisely, I order the interest rate last, thus allowing for an immediate reaction of monetary policy to innovations in house prices. Figure 13 presents the impulse responses of the alternative identification structure. As expected, the impulses are almost the same using the alternative identification structure, since the reduced-form innovations are highly uncorrelated across equations.

V. __CONCLUSIONS__

This paper studied the relationship between interest rates and real house prices in three industrialized countries, namely Canada, the USA and Japan using three individual-country VARs that included real GDP, inflation and real equity prices apart from the two variables that were of main interest. The results of the empirical analysis are interesting. First in all three countries, Granger causality tests indicated that there is evidence of a significant bidirectional link between nominal short-term interest rates and the growth rate of real house prices. Second, analysis via impulse responses verified the expected cumulative response of the one variable to a shock in the other variable. Particularly after an interest rate shock, the growth rate of real house prices falls, with the duration of the effect varying from four quarters (USA) to twelve quarters (Canada). After a shock in the growth rate of real house prices, interest rates rise with the duration of the effect varying from six quarters (Canada) to eleven quarters (Japan). But the hot question that still brings about open to debate arguments is "Should central banks respond to movements in asset prices?". Before answering to that question we must hypothesize that a central bank has superior information over the private sector that a bubble already exists, because it makes no sense if a central bank responds to movements in asset prices that are supported by fundamentals. Second we must have in mind that the primary objective of a central bank should be inflation targeting and GDP stability, so monetary authorities should not respond to asset price movements if such a response is menacing to the inflation targeting objective. Variance decompositions for the country of Canada indicate that at a horizon of ten quarters, shocks in the interest rate account for 19% of the variation in the growth rate of real house prices, so at first sight interest rates could successfully mitigate house price swings. However this would be done at the expense of GDP stability, since at the same horizon interest rate shocks account for 10% of the variation in the growth rate of real GDP. For the USA, interest rate shocks account for 11% of the variation in the growth rate of real house prices but also account for 10% and 9% of the variation in the growth rate of real GDP and inflation respectively. Finally, for Japan interest rate shocks account for only 5% of the variation in the growth rate of real house prices, indicating that monetary policy intervention can play a minor role in controlling house prices. These findings suggest that monetary authorities should be concentrated on targeting inflation and short run economic stability and that asset prices should affect monetary policy only to the extent that they affect the inflation forecast of a central bank.

REFERENCES

1) Ahearne, Alan G., John Ammer, Brian M. Doyle, Linda S. Kole and Robert F. Martin (2005), "House Prices and Monetary Policy: A Cross-Country Study," Board of Governors of the Federal Reserve System, International Finance Discussion Papers No. 841.

2) Akerlof George (1970), "The Market for "Lemons": Quality Uncertainty and the Market Mechanism". The Quarterly Journal of Economics, Vol. 84, No.3. (Aug., 1970), pp. 488-500.

3) Altissimo Filippo, Evaggelia Georgiou, Teresa Sastre, Maria Teresa Valderrama, Gabriel Sterne, Marc Stocker, Mark Weth, Karl Whelan and Alpo Willman (2005), "Wealth and Asset Price Effects on Economic Growth", ECB Occasional Paper Series, No.29.

4) Angeloni, Ignazio, Anil K. Kashyap and Benoit Mojon (2003), Monetary Policy Transmission in the Euro Area, Cambridge University Press, Cambridge.

5) Aoki, Kosuke, James Proudman and Gertjan Vlieghe (2001), "Why Housing Prices Matter?" Bank of England, Quarterly Bulletin, Winter.

6) Assenmacher – Wesche K. and S. Gerlach (2008), Monetary Policy, Asset Prices and Macroeconomic Conditions: a Panel- VAR Study. National Bank of Belgium Working Paper No. 149.

7) Assenmacher – Wesche K. and S. Gerlach (2008), Ensuring Financial Stability: Financial Structure and the Impact of Monetary Policy on Asset Prices. Institute for Empirical Research in Economics, University of Zurich Working Paper No. 361.

8) Bernanke, B. and A.S. Blinder (1988), "Credit, Money, and Aggregate Demand" American Economic Review, Vol. 78, no. 2, pp 435-439.

9) Bernanke, Ben S. and Blinder Alan S. (1992), "The Federal Funds Rate and the Channels of Monetary Transmission" The American Economic Review, Vol. 82, No. 4. (Sep., 1992), pp. 901-921.

10) Bernanke, Ben S. and Gertler Mark (1989): "Agency Costs, Net Worth, and Business Fluctuations", American Economic Review, 79(1), 14-31.

11) Bernanke, Ben S & Gertler Mark : 'Inside the Black Box : The Credit Channel of Monetary Policy Transmission' Journal of Economic Perspective 1995 Vol 9

12) Bernanke, Ben S. and Mark Gertler (2001), "Should Central Banks Respond to Movements in Asset Prices?", American Economic Review, vol. 91

13) Bernanke, Ben S., Gertler Mark and Gilchrist Simon (1996), "The Financial Accelerator and the Flight to Quality", The Review of Economics and Statistics, Vol. 78, No.1.(Feb., 1996), pp. 1-15.

14) Bjornland Hilde C. and Jacobsen Dag Henning (2008), "The role of house prices in the monetary policy transmission mechanism in the U.S." Norges Bank Working Paper No 2008/24.
Borio, Claudio and Philip Lowe (2002), "Asset Prices, Financial and Monetary Stability: Exploring the Nexus," BIS Working Paper No 114.

15) Borio C., and McGuire P., «Twin peaks in equity and housing prices?», BIS Quarterly Review, March 2004

16) Brissimis, S. N, Magginas, N. S., (2004) Forward-Looking Information in VAR Models and the Price Puzzle. Bank of Greece, Working Paper, No 10.

17) Calhoun C. (1996) "OFHEO House Price Indexes : HPI Technical Description". Office of Federal Housing Enterprise Oversight.

18) Case, Karl E. and John M. Quigley and Robert J. Shiller. 2005. "Comparing Wealth Effects: The Stock Market versus the Housing Market." Advances in Macroeconomics, 5, no. 1: article 1.

19) Cecchetti , S., Genberg, H., and S. Wadhwani (2002): "Asset prices in a flexible inflation targeting framework" National Bureau of Economic Research Working Paper 8970.

20) Cottarelli, C. and A. Kourelis (1994), "Financial Structure, Bank Lending Rates, and the Transmission Mechanism of Monetary Policy," IMF Working Paper, no. 39, March.

21) Cournède B. (2005). "House Prices and Inflation in the Euro Area". OECD Economics Department Working Papers, No. 450, OECD Publishing.

22) Debelle Guy (2004), 'Households Debt and the Macro economy', BIS Quarterly Review March 2004.

23) Debelle, G (2004), 'Macroeconomic implications of rising household debt', BIS Working Paper no.153.

24) Dickey, D. A. and Fuller, W. A. (1981) Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root, Econometrica 49(4), 1057—72.

25) European Central Bank. The implementation of monetary policy in the Euro area. General documentation on Eurosystem monetary policy instruments and procedures. November 2008. Page 6-64.

26) European Central Bank. "Structural factors in the EU housing market", March 2003.

27) Girouard, N. and S. Blöndal (2002), "House prices and economic activity", OECD Working Paper No. 279.

28) Goodhart, Charles A.E. and Boris Hofmann (2008) "House Prices, money, credit, and the Macroeconomy", OxfordReview of Economic Policy, Volume 24, Number1, 2008, pp.180-205 .

29) Granger, C. W. J. (1969) Investigating Causal Relations by Econometric Models and Cross-Spectral Methods, Econometrica 37, 424—38
Hofmann, Boris (2003), "Bank Lending and Property Prices: Some International Evidence," HKIMR Working Paper No. 22.

30) Hördahl Peter and Frank Packer (2007), "Understanding asset prices: an overview" BIS paper no.34: 2006 Autumn Meeting of Central Bank Economists.

31) Iacoviello M. (2000), House Prices and the Macroeconomy in Europe: Results from a Structural VAR Analysis.

32) Iacoviello, Matteo (2002), "House Prices and Business Cycles in Europe: A VAR Analysis,"Boston College Working Papers in Economics, No 540.

33) International Monetary Fund (2008), "The Changing Housing Cycle and the Implications for Monetary Policy," World Economic Outlook, 2008, 103-132.

34) Ireland P. (2005) "The Monetary Transmission Mechanism". Boston College Economics Department Working papers in Economics October 2005.

35) Kearl, J. R., and Frederic S. Mishkin. 1977. "Illiquidity, the Demand for Residential Housing, and Monetary Policy," Journal of Finance, December, pp. 1571-86.

36) Ludvigson S., Steindel C. and Lettau M. "Monetary Policy Transmission through the Consumption-Wealth Channel." FRBNY Economic Policy Review/May 2002

37) Ludwig, Alexander and Torsten Sløk (2002), The impact of changes in stock prices and house prices on consumption in OECD countries, IMF Working Paper No. 02/1.

38) Lütkepohl H., (2007). "Econometric Analysis with Vector Autoregressive Models" European University Institute Working Papers ECO 2007/11.

39) Mishkin, Frederic, 1976 - "Illiquidity, Consumer Durable Expenditure, and Monetary Policy", American Economic. Review 66, pp. 642-654.

40) Mishkin, F. (2001) " The transmission mechanism and the role of asset prices in monetary policy" NBER Working Paper No 8617.

41) Modigliani, F. (1986), Life Cycle, Individual Thrift and the Wealth of Nations, The American Economic Review, Vol. 76(3), pg. 297-313

42) Mojon, B. (2000), "Financial Structure and the Interest Rate Channel of ECB Monetary Policy?" ECB Working Paper Series, no. 40, November.

43) Peersman, G. and F. Smets (2001), "Transmission Mechanism in the Euro Area: More Evidence from VAR Analysis," ECB Working Paper, no. 91, December.

44) Qin Duo (2006) " VAR Modelling Approach and Cowles Commission Heritage" Queen Mary, University of London, Economics Department, Working Paper No.557 March 2006.

45) Runkle, D.E (1987) "Vector Autoregressions and Reality", Federal Reserve Bank of Minneapolis Research Department Staff Report 107.

46) Selody, Jack and Carolyn Wilkins. 2007. "Asset-Price Misalignments and Monetary Policy: How Flexible Should Inflation-Targeting Regimes Be?" Discussion Paper, 2007-6. Ottawa: Bank of Canada.

47) Sims, C.A. (1980) "Macroeconomics and Reality", Econometrica,48,pp.1-48.

48) Stock J. and Watson M. (2001). "Vector Autoregressions".

49) Sutton, Gregory (2002), Explaining changes in house prices. BIS Quarterly Review, September 2002.

50) Tsatsaronis K. and Zhu H., "What drives housing price dynamics: cross-country evidence" BIS Quarterly Review, March 2004.

51) Tucker, P (2003): "Credit conditions and monetary policy", Bank of England Quarterly Bulletin, autumn, pp 366–78.

52) Wadhwani, S (2002): "Household indebtedness, the exchange rate and risks to the UK economy", Bank of England Quarterly Bulletin, summer, pp 228–36.

53) Zhu, H., (2003), ''The Importance of Property Markets for Monetary Policy and Financial Stability'', BIS. Papers No. 21

Figure 1 The Implementation of monetary policy in the euro area.

The primary objective of ECB is to preserve price stability in the euro area. Monetary stability is defined as a situation in which inflation does not exceed 2% per year. For measuring inflation in the euro zone, ECB uses the Harmonized Index of Consumer Prices. A secondary purpose, is to intervene whenever necessary, affecting short-term production and employment. In the long run, employment and goods services produced, are not dependent on monetary policy, but on other factors such as technological development and productivity of capital and labour. For example, if the economy is in recession, ECB may intervene and stimulate the economy, providing it with liquidity. However, while an expansionary monetary policy appears to be effective and thus attractive, it may have unpleasant consequences, if not exercised consistently. If ECB is constantly trying to stimulate the economy, then the total demand will grow very rapidly and when the economy reaches its potential output level, it would not respond to such high demand, with the loss of control of inflation.

The main interest rates ECB is trying to influence are the interbank market rates. In this way, ECB has the whole control of liquidity in the financial system. The interbank market rates in the Euro-zone are Euribor for deposits of one, three, six and twelve months and the EONIA rate which is the interbank rate for overnight deposits. The instruments of monetary policy that ECB adopts are A) Open Market Operations, B) the provision of fixed facilities and C) the setting of minimum reserves for commercial banks on accounts in the Eurosystem.

Open market operations are the principal tool of ECB to affect interest rates. It can purchase securities via outright transactions with commercial banks, providing the banking system with liquidity and forcing interbank interest rates to fall. It can also sell securities to commercial banks, absorbing the liquidity of the banking sector and forcing interbank rates to increase. However, reverse transactions are the main open market instrument of ECB, where it buys or sells eligible assets from commercial banks with the agreement to reverse the transaction (sell or buy) at a future point in time. The difference between the purchase price and the repurchase price of the assets depends on the interest rate that is specified over the maturity of the transaction.

More specifically, when ECB buys the assets from commercial banks, it holds these assets as collateral and provides the banks with money. At a future agreed date these banks repurchase the assets, returning ECB its money plus the interest based on the repo rate. (Repurchase agreement). On the other hand, when ECB sells assets to commercial banks, it absorbs their liquidity and at a future date repurchases the assets, returning the money that it borrowed plus the interest. (Reverse repurchase agreement). These operations are carried out by the national central banks of the Eurosystem via standardised auctions at regular intervals. Reverse transactions are executed a) with a weekly frequency and a maturity of one week. These transactions target the control of the short-term interbank interest rates. B) with a monthly frequency and a maturity of 3 months. These transactions target the provision of medium-term liquidity for commercial banks and the control of the medium-tern interbank interest rates. C) with no predetermined frequency and maturity. These transactions are carried out whenever an unexpected fluctuation of liquidity occurs in the banking sector.

Standing facilities aim at the provision or the absorption of liquidity with a duration of one day. Commercial banks may use the *marginal lending facility* to obtain overnight liquidity from the national central banks against eligible assets as collateral. Also they can use the *deposit facility* to make overnight deposits with the national central banks. *Minimum reserves* are the third way with which ECB can affect interbank liquidity. The amount of minimum reserves to be held by each institution is determined by its liabilities. A rise of the minimum reserves that each bank is obliged to hold, creates lack of interbank liquidity as there will be fewer banks having redundant reserves to offer while there will be much more banks asking for reserves to satisfy the minimum reserve requirements.[25]

[25]ECB. The implementation of monetary policy in the Euro area. General documentation on Eurosystem monetary policy instruments and procedures. November 2008. Page 6-64.

Figure 2: Nominal house prices over the period 1980Q1-2008Q4

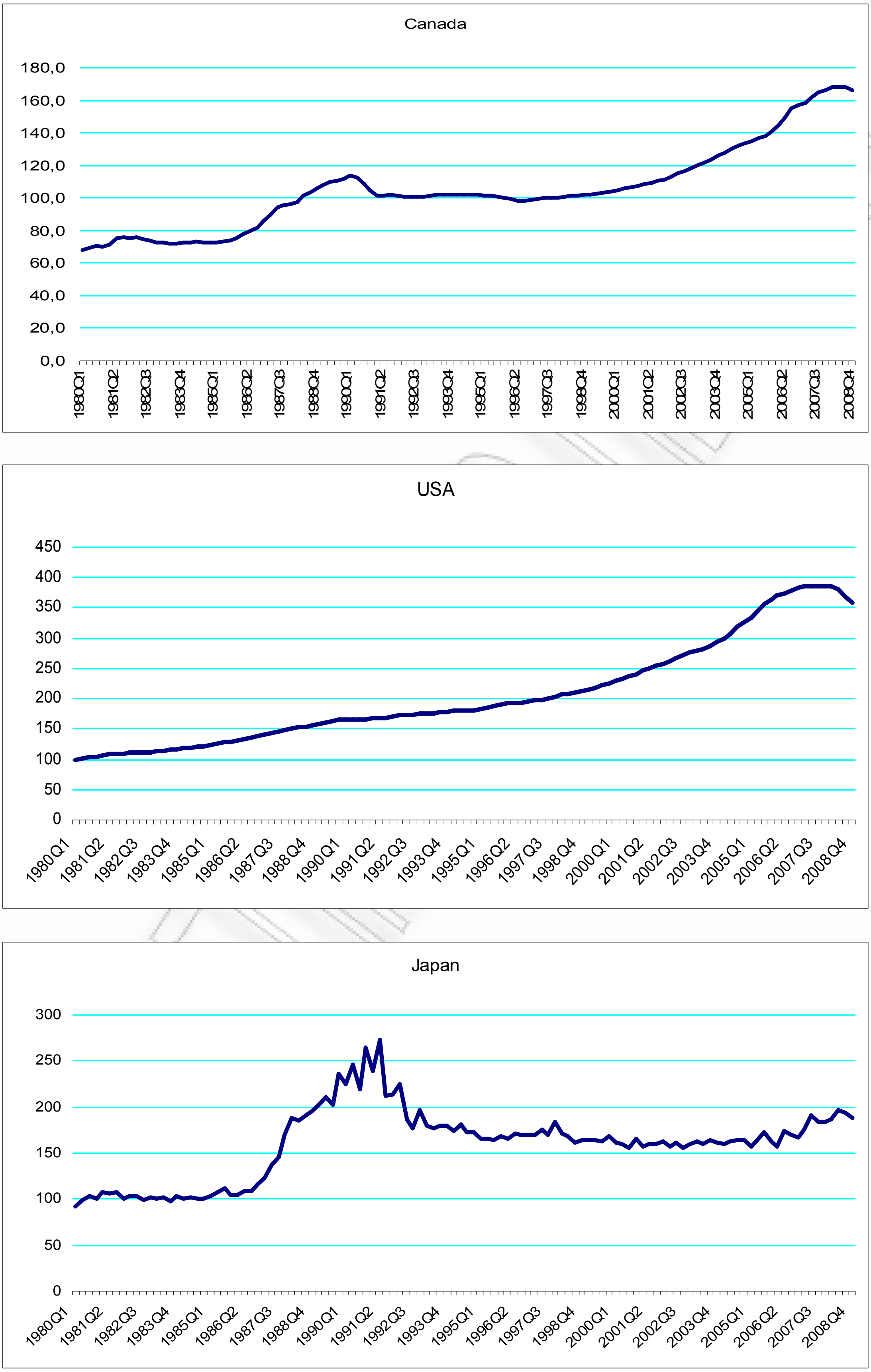
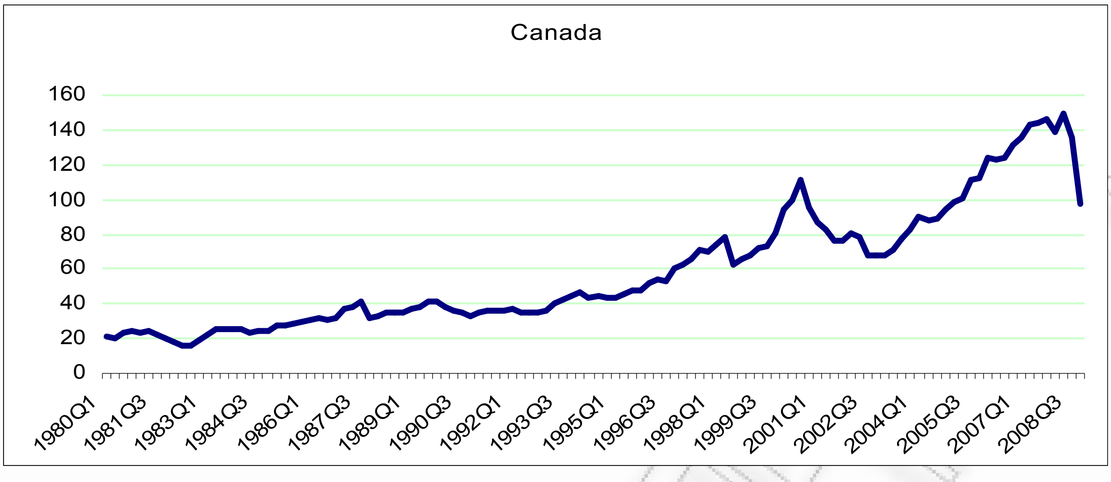
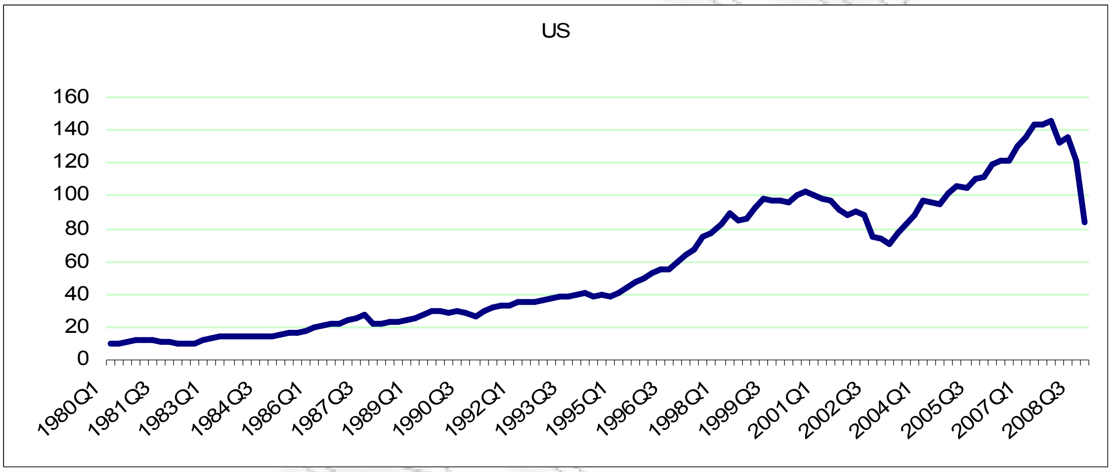


Figure 3 Nominal equity prices over the period 1980Q1-2008Q4 (2000=100)





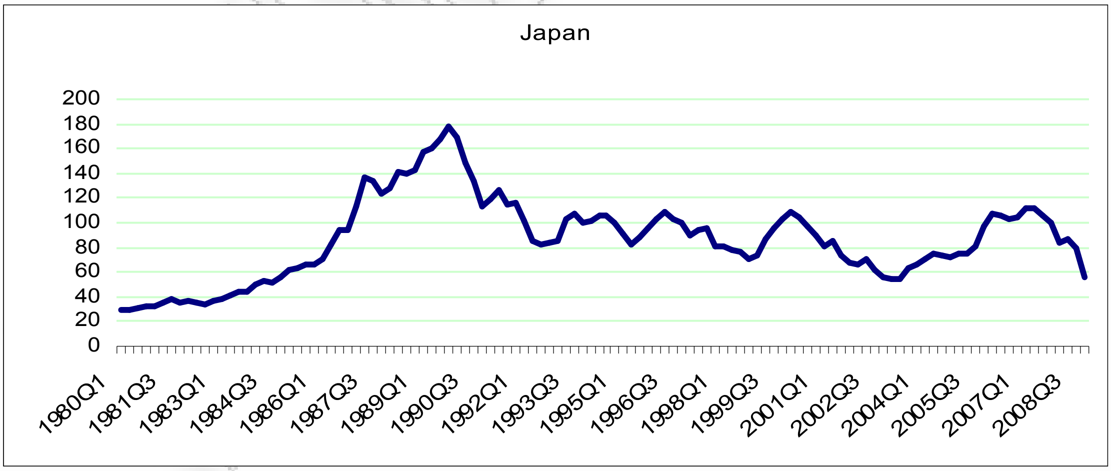


Figure 4a: unit root tests Canada

Augmented Dickey-Fuller test		t- statistic	Prob.*
CAN logRGDP	Trend and intercept, LL=3	-3.035356	0.1276
	Intercept, LL=1	-0.205594	0.9333
	None, LL=1	3.503810	0.9999
CAN DlogRGDP	Trend and intercept, LL=3	-4.522727	0.0022
	Intercept, LL=3	-4.617565	0.0002
	None, LL=2	-2.224770	0.0258
CAN INF	Trend and intercept, LL=4	-3.517843	0.0425
	Intercept, LL=4	-4.084599	0.0016
	None, LL=4	-3.582079	0.0004
CAN I	Trend and intercept, LL=1	-3.492111	0.0451
	Intercept, LL=0	-1.606090	0.4762
	None, LL=0	-1.718051	0.0813
CAN DI	Trend and intercept, LL=0	-8.209080	0.0000
	Intercept, LL=0	-8.242764	0.0000
	None, LL=0	-8.209988	0.0000
CAN logRHP	Trend and intercept, LL=1	-2.516627	0.3197
	Intercept, LL=1	-2.797710	0.0619
	None, LL=1	-1.611387	0.1007
CAN DlogRHP	Trend and intercept, LL=0	-4.797466	0.0009
	Intercept, LL=0	-4.323970	0.0007
	None, LL=0	-4.337506	0.0000
CAN logREP	Trend and intercept, LL=0	-2.884824	0.1715
	Intercept, LL=0	-1.023929	0.7429
	None, LL=0	-1.126723	0.2351
CAN DlogREP	Trend and intercept, LL=0	-7.011239	0.0000
	Intercept, LL=0	-7.075963	0.0000
	None, LL=0	-7.107972	0.0000

*MacKinnon (1996) one-sided p-values.

Figure 4b: unit root tests USA

Augmented Dickey-Fuller test		t- statistic	Prob.*
US logRGDP	Trend and intercept, LL=2	-2.599921	0.2814
	Intercept, LL=3	-0.436013	0.8978
	None, LL=2	4.528220	1.0000
US DlogRGDP	Trend and intercept, LL=1	-5.646151	0.0000
	Intercept, LL=1	-5.663187	0.0000
	None, LL=1	-2.961667	0.0034
US INF	Trend and intercept, LL=8	-3.796710	0.0207
	Intercept, LL=8	-3.508219	0.0097
	None, LL=8	-2.005440	0.0435
US I	Trend and intercept, LL=1	-2.486730	0.3341
	Intercept, LL=1	-1.859865	0.3500
	None, LL=1	-1.327304	0.1697
US DI	Trend and intercept, LL=0	-9.567943	0.0000
	Intercept, LL=0	-9.605109	0.0000
	None, LL=0	-9.633150	0.0000
US logRHP	Trend and intercept, LL=3	-0.136275	0.9936
	Intercept, LL=1	3.188009	1.0000
	None, LL=3	2.035072	0.9898
US DlogRHP	Trend and intercept, LL=2	-3.569609	0.0374
	Intercept, LL=2	-3.041013	0.0344
	None, LL=2	-2.438760	0.0149
US logREP	Trend and intercept, LL=1	-2.466344	0.3441
	Intercept, LL=0	-0.521608	0.8816
	None, LL=0	-2.523951	0.0119
US DlogREP	Trend and intercept, LL=0	-8.314457	0.0000
	Intercept, LL=0	-8.352210	0.0000
	None, LL=0	-7.864715	0.0000

*MacKinnon (1996) one-sided p-values.

Figure 4c: unit root tests Japan

Augmented Dickey-Fuller test		t- statistic	Prob.*
JPN logRGDP	Trend and intercept, LL=0	-0.827253	0.9593
	Intercept, LL=0	-3.742551	0.0047
	None, LL=3	2.010468	0.9892
JPN DlogRGDP	Trend and intercept, LL=0	-9.106970	0.0000
	Intercept, LL=2	-3.218835	0.0215
	None, LL=2	-2.375175	0.0176
JPN INF	Trend and intercept, LL=0	-3.719716	0.0250
	Intercept, LL=0	-3.919919	0.0026
	None, LL=0	-3.756388	0.0002
JPN I	Trend and intercept, LL=3	-2.431710	0.3614
	Intercept, LL=1	-1.934623	0.3155
	None, LL=1	-2.164152	0.0299
JPN DI	Trend and intercept, LL=0	-6.434945	0.0000
	Intercept, LL=0	-6.389234	0.0000
	None, LL=0	-6.297333	0.0000
JPN logRHP	Trend and intercept, LL=4	-2.573110	0.2934
	Intercept, LL=4	-2.638059	0.0886
	None, LL=4	0.402890	0.7980
JPN DlogRHP	Trend and intercept, LL=3	-3.074346	0.1178
	Intercept, LL=3	-3.058156	0.0329
	None, LL=3	-3.023780	0.0028
JPN logREP	Trend and intercept, LL=1	-1.844893	0.6760
	Intercept, LL=1	-1.972287	0.2986
	None, LL=1	-1.866971	0.0593
JPN DlogREP	Trend and intercept, LL=0	-6.307190	0.0000
	Intercept, LL=0	-6.087363	0.0000
	None, LL=0	-6.134321	0.0000

*MacKinnon (1996) one-sided p-values.

Figure 5: VAR Lag Order Selection Criteria CANADA

VAR Lag Order Selection Criteria[26]
Endogenous variables: D(LOGRGDP) INF D(I) D(LOGRHP) D(LOGREP)
Exogenous variables: C
Date: 04/01/09 Time: 22:21
Sample: 1981Q1 2008Q4
Included observations: 107

Lag	LogL	LR	FPE	AIC	SC	HQ
0	963.6216	NA	1.14e-14	-17.91816	-17.79326	-17.86753
1	1157.018	365.1034	4.89e-16	-21.06576	-20.31637*	-20.76196*
2	1181.977	44.78620	4.91e-16	-21.06499	-19.69111	-20.50804
3	1205.907	40.70284	5.04e-16	-21.04498	-19.04661	-20.23487
4	1237.593	50.93522*	4.52e-16*	-21.16996*	-18.54709	-20.10669

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

---

[26] VAR models are estimated using the same lag length for all variables in all equations of the model. The lag length is determined using a statistical criterion such as the Akaike information criterion (AIC), Schwarz information criterion (SIC), Final prediction error (FPE), Hannan-Quinn information criterion (HQ) or the sequential modified LR test statistic. Lütkepohl (2007) explicitly presents the various lag length criteria stating that the general form of such criteria is $C(m) = \log \det(\hat{\Sigma}_m) + c_T \phi(m)$,

where $\hat{\Sigma}_m$ is the estimator of the residual covariance matrix for a model of order m, $\phi(m)$ =mK^2 is a positive function of the order m which penalizes large VAR orders and c_T is a sequence which may depend on the sample size and identifies the specific criterion. More specifically, AIC(m) $= \log\det(\hat{\Sigma}_m) + \frac{2}{T} mK^2$,where c_T =2/T, HQ(m) $= \log\det(\hat{\Sigma}_m) + \frac{2\log\log T}{T} mK^2$, where c_T = =2loglogT/T and SC(m) $= \log\det(\hat{\Sigma}_m) + \frac{\log T}{T} mK^2$, where c_T =logT/T. The sequential modified LikelihoodRatio test statistic $LR = (T-m)(\ln|\Sigma_{t-1}| - \ln|\Sigma_t|) \sim \chi^2(n^2)$, where T is the number of observations and m is the number of parameters estimated in each equation of the VAR(t) model. If the LR statistic< critical value, we reject the null of k-1 lags over k lags.

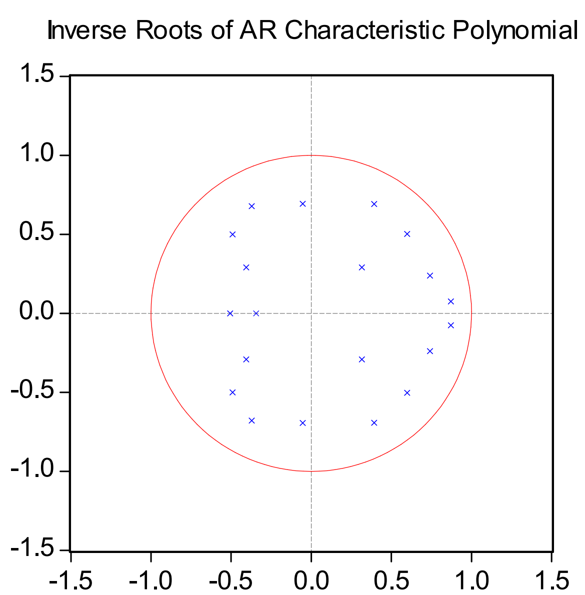
Figure 6: VAR Diagnostic tests of the residuals CANADA

a) VAR stability condition

Roots of Characteristic Polynomial
Endogenous variables: D(LOGRGDP) INF D(I) D(LOGRHP) D(LOGREP)
Exogenous variables: C
Lag specification: 1 4
Date: 04/01/09 Time: 19:04

Root	Modulus
0.871741 + 0.074850i	0.874949
0.871741 - 0.074850i	0.874949
0.392963 + 0.692516i	0.796240
0.392963 - 0.692516i	0.796240
0.598480 + 0.502800i	0.781656
0.598480 - 0.502800i	0.781656
0.740464 + 0.238682i	0.777982
0.740464 - 0.238682i	0.777982
-0.371869 - 0.677919i	0.773215
-0.371869 + 0.677919i	0.773215
-0.490540 - 0.499139i	0.699835
-0.490540 + 0.499139i	0.699835
-0.053012 - 0.692878i	0.694903
-0.053012 + 0.692878i	0.694903
-0.506445	0.506445
-0.405798 + 0.291720i	0.499772
-0.405798 - 0.291720i	0.499772
0.314935 + 0.290834i	0.428682
0.314935 - 0.290834i	0.428682
-0.344957	0.344957

No root lies outside the unit circle.
VAR satisfies the stability condition.



b) White heteroskedasticity test – Autocorrelation LM test

VAR Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Date: 04/01/09 Time: 19:20
Sample: 1981Q1 2008Q4
Included observations: 107

Joint test:

Chi-sq	df	Prob.
649.8091	600	0.0779

Individual components:

Dependent	R-squared	F(40,66)	Prob.	Chi-sq(40)	Prob.
res1*res1	0.491682	1.596002	0.0456	52.61001	0.0874
res2*res2	0.341473	0.855593	0.6987	36.53763	0.6269
res3*res3	0.408683	1.140382	0.3132	43.72909	0.3161
res4*res4	0.664468	3.267564	0.0000	71.09808	0.0018
res5*res5	0.367887	0.960292	0.5473	39.36388	0.4987
res2*res1	0.429171	1.240535	0.2159	45.92134	0.2402
res3*res1	0.324135	0.791317	0.7853	34.68249	0.7080
res3*res2	0.253459	0.560192	0.9746	27.12008	0.9401
res4*res1	0.624565	2.744907	0.0001	66.82850	0.0049
res4*res2	0.435930	1.275169	0.1882	46.64451	0.2180
res4*res3	0.423747	1.213327	0.2397	45.34096	0.2590
res5*res1	0.382060	1.020164	0.4628	40.88047	0.4316
res5*res2	0.298325	0.701517	0.8851	31.92080	0.8150
res5*res3	0.489423	1.581638	0.0488	52.36826	0.0910
res5*res4	0.431110	1.250387	0.2077	46.12882	0.2337

VAR Residual Serial Correlation LM Tests
H0: no serial correlation at lag order h
Date: 04/01/09 Time: 19:22
Sample: 1981Q1 2008Q4
Included observations: 107

Lags	LM-Stat	Prob
1	32.49584	0.1442
2	20.70664	0.7088
3	30.65508	0.2007
4	36.72161	0.0613
5	30.39339	0.2099
6	27.58041	0.3275
7	22.75336	0.5920
8	27.25526	0.3433

Probs from chi-square with 25 df.

Figure 7: Impulse responses to orthogonalized one S.D. innovations in a two-standard-error confidence band. CANADA

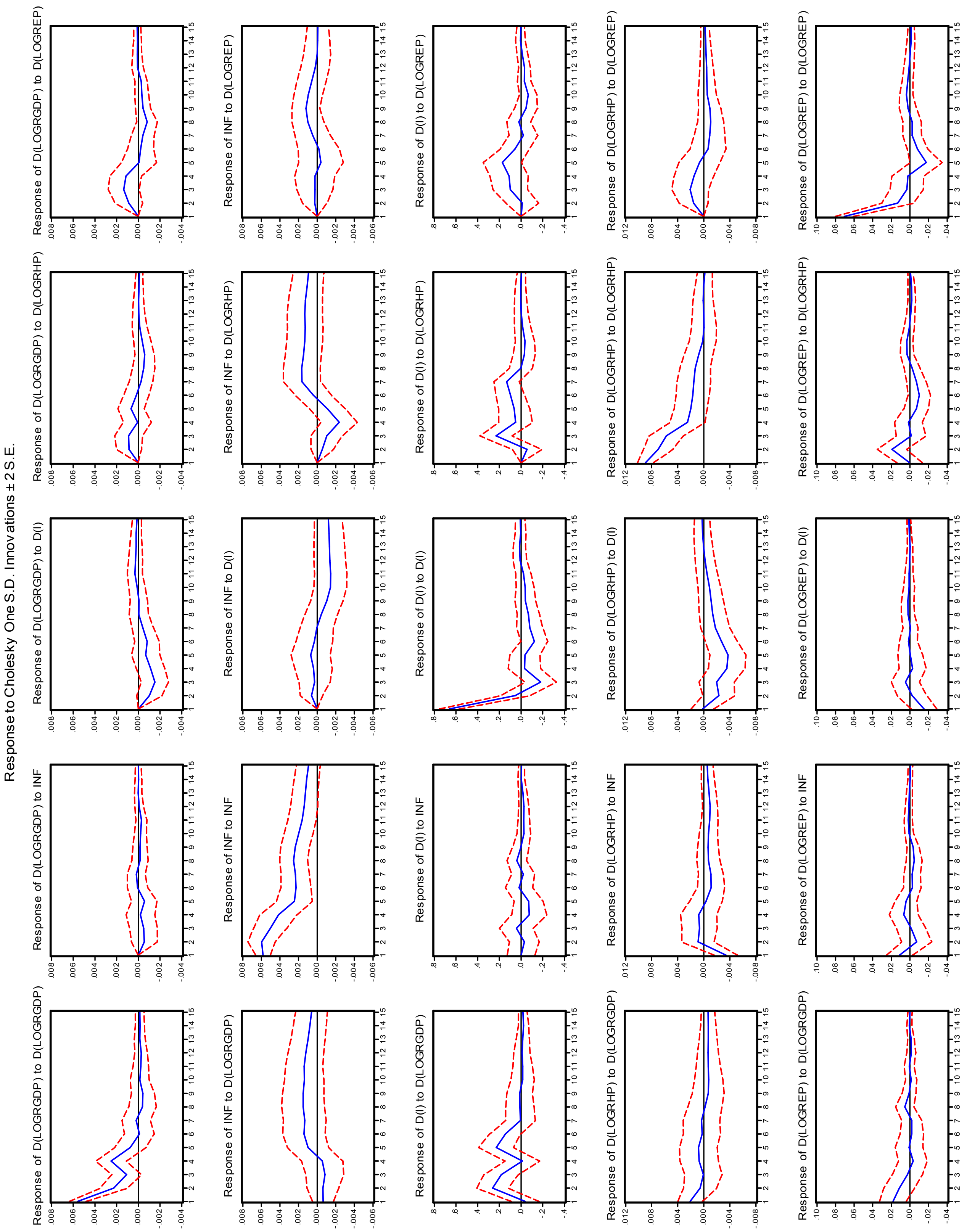


Figure 8: Variance Decomposition of the variables using Cholesky Decomposition for CANADA

Variance Decomposition of D(LOGRGDP):

Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.005586	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.006258	92.75341	0.797394	2.694258	1.840496	1.914441
3	0.006746	82.35691	1.219754	7.488580	3.298705	5.636047
4	0.007381	80.39797	1.092693	8.633040	2.765178	7.111121
5	0.007501	78.80104	1.635612	9.215084	3.455655	6.892609
6	0.007551	77.78439	1.622482	10.24062	3.470087	6.882422
7	0.007583	77.18933	1.665003	10.46341	3.553944	7.128320
8	0.007656	76.00512	1.676887	10.27222	3.925300	8.120465
9	0.007705	75.35004	1.699343	10.14828	4.459536	8.342794
10	0.007726	74.97089	1.762871	10.11224	4.668712	8.485288

Variance Decomposition of INF:

Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.005856	1.187943	98.81206	0.000000	0.000000	0.000000
2	0.008437	1.113355	97.85179	0.508708	0.440495	0.085656
3	0.009925	1.520480	96.51624	0.442277	1.398809	0.122197
4	0.011041	1.471869	92.14387	0.479065	5.758074	0.147124
5	0.011431	2.100908	90.51834	0.812338	6.300971	0.267443
6	0.011755	3.455403	89.36038	0.833773	6.075369	0.275078
7	0.012178	4.401427	86.96863	0.777826	7.444163	0.407957
8	0.012683	5.465283	84.14263	0.840791	8.558494	0.992801
9	0.013168	6.359134	81.29632	1.406985	9.175495	1.762062
10	0.013562	7.030319	78.78051	2.431720	9.610091	2.147356

Variance Decomposition of D(I):

Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.662046	0.338563	0.000366	99.66107	0.000000	0.000000
2	0.716623	13.58830	0.184834	85.60843	0.592944	0.025493
3	0.802292	15.96878	0.434575	73.40080	8.671748	1.524097
4	0.815551	15.47643	1.288831	71.18695	8.763000	3.284791
5	0.870246	20.51852	1.789821	62.69356	8.213116	6.784977
6	0.897714	21.85561	1.721606	60.77249	8.894827	6.755466
7	0.911588	21.19837	1.727857	59.72320	10.73921	6.611360
8	0.915243	21.03998	1.888309	59.81130	10.65362	6.606801
9	0.917869	20.93574	1.877773	59.66235	10.70011	6.824032
10	0.922346	20.76297	1.942139	59.25342	10.75201	7.289457

Variance Decomposition of D(LOGRHP):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.009811	4.578284	12.02298	0.041019	83.35772	0.000000
2	0.012422	3.057573	8.003227	3.499518	83.86214	1.577539
3	0.014002	2.407595	6.511304	4.763185	82.85914	3.458776
4	0.014771	2.393655	6.123195	10.02269	77.31207	4.148385
5	0.015404	2.484201	5.681020	15.05339	72.78462	3.996766
6	0.015788	2.392136	5.919394	17.29771	70.41749	3.973269
7	0.016027	2.367368	6.205041	18.01330	69.24355	4.170747
8	0.016193	2.333068	6.277300	18.38172	68.48323	4.524681
9	0.016305	2.477878	6.354922	18.60546	67.77504	4.786693
10	0.016371	2.675911	6.494396	18.74058	67.23820	4.850917

Variance Decomposition of D(LOGREP):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.075249	5.843970	2.205166	4.087827	0.001765	87.86127
2	0.079962	7.203321	2.778789	3.705969	5.833171	80.47875
3	0.080238	7.253658	2.785909	4.038235	5.821834	80.10036
4	0.080676	7.360888	3.416632	4.128668	5.791853	79.30196
5	0.082961	6.970876	3.486781	3.908462	6.182462	79.45142
6	0.084037	6.853555	3.492004	3.841695	7.447611	78.36513
7	0.084429	6.846383	3.545678	3.813656	8.070794	77.72349
8	0.084831	7.201623	3.808803	3.836394	8.083188	77.06999
9	0.085018	7.179946	3.961393	3.891330	8.178566	76.78877
10	0.085187	7.179862	3.953903	3.886083	8.296722	76.68343

Cholesky Ordering: D(LOGRGDP) INF D(I) D(LOGRHP) D(LOGREP)

Figure 9: Impulse responses to orthogonalized one S.D. innovations in a two-standard-error confidence band. USA

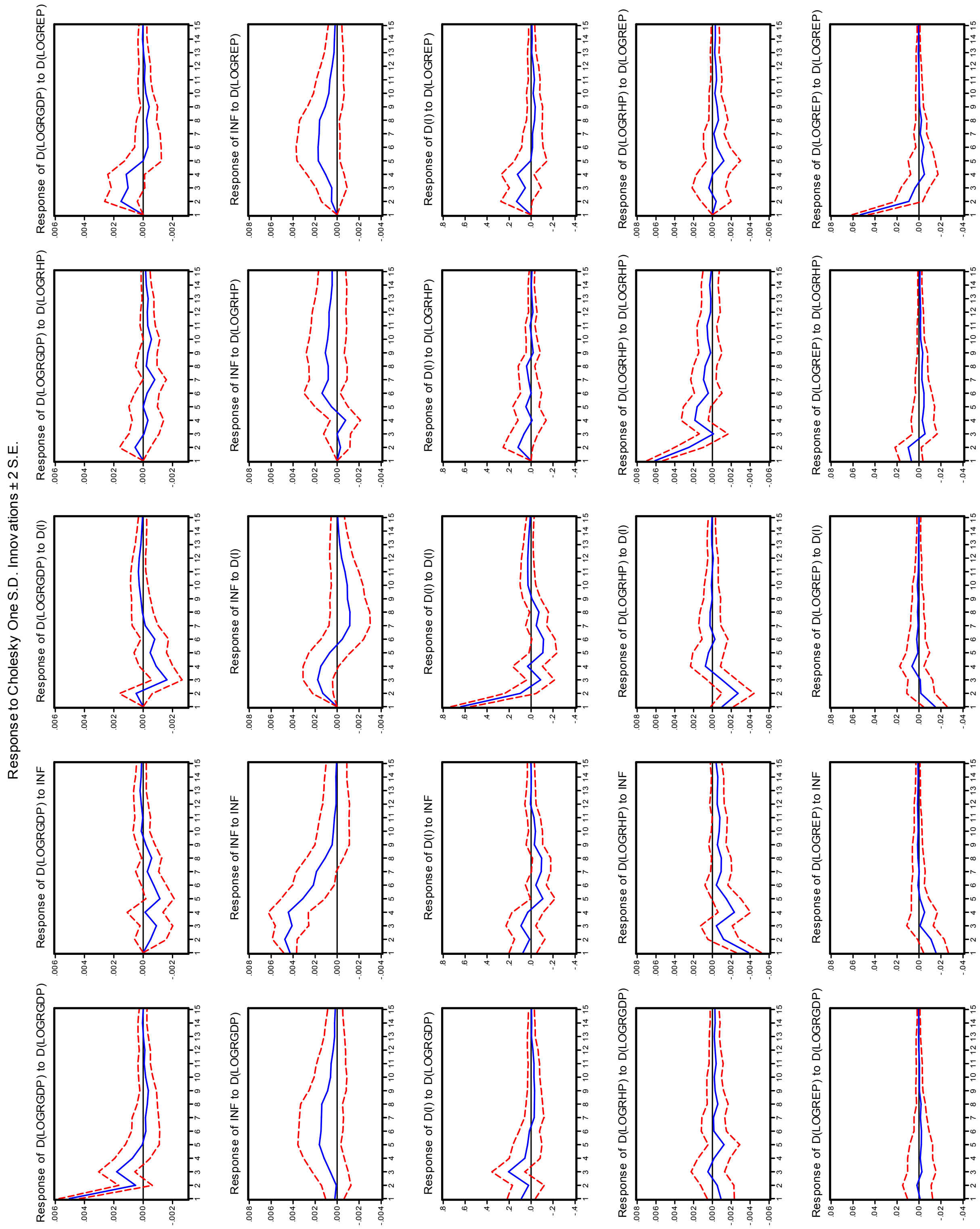


Figure 10 Variance Decomposition of the variables using Cholesky Decomposition for USA

Variance Decomposition of D(LOGRGDP):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.005039	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.005359	89.37438	0.887149	0.792358	1.034768	7.911344
3	0.006040	79.23301	2.941270	7.847070	0.822750	9.155901
4	0.006265	74.98607	2.781068	9.301806	1.048486	11.88257
5	0.006388	72.12009	5.914787	9.529536	1.008313	11.42727
6	0.006495	69.85893	6.960463	10.72443	1.146399	11.30977
7	0.006559	68.55525	7.003750	10.56286	2.561964	11.31617
8	0.006598	67.93158	7.683532	10.44328	2.638593	11.30302
9	0.006633	67.50256	7.680434	10.38356	2.850570	11.58288
10	0.006669	66.85293	7.633937	10.43233	3.545700	11.53511

Variance Decomposition of INF:						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.004283	0.218935	99.78107	0.000000	0.000000	0.000000
2	0.006554	0.107312	95.20582	3.888495	0.219160	0.579215
3	0.007965	0.690640	90.86547	7.523084	0.148393	0.772415
4	0.009401	2.095037	87.47279	7.857448	0.773490	1.801235
5	0.010211	4.267441	83.42898	7.099097	0.906543	4.297939
6	0.010777	5.694371	78.89187	6.571589	2.419997	6.422169
7	0.011241	6.829481	75.33228	7.098698	2.738503	8.001034
8	0.011580	7.893143	71.88215	7.724701	3.065237	9.434773
9	0.011759	8.197931	69.85637	8.135805	3.799954	10.00994
10	0.011869	8.297341	68.64321	8.588096	4.257222	10.21413

Variance Decomposition of D(I):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.650005	1.834146	1.260670	96.90518	0.000000	0.000000
2	0.681167	1.781978	1.179983	90.26022	3.027654	3.750160
3	0.727424	9.535736	2.629704	80.58477	3.442281	3.807504
4	0.741305	9.774276	2.686129	77.78030	3.331283	6.428014
5	0.758914	9.496913	4.566650	76.25430	3.547206	6.134929
6	0.768815	9.295111	4.780890	76.46253	3.456582	6.004884
7	0.776684	9.246826	6.074277	75.29276	3.472623	5.913510
8	0.788226	9.121238	7.383656	73.95155	3.638442	5.905112
9	0.790659	9.226738	7.492224	73.50864	3.680466	6.091936
10	0.792887	9.281606	7.712807	73.22533	3.665500	6.114753

Variance Decomposition of D(LOGRHP):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.007349	1.470419	27.38379	1.980380	69.16542	0.000000
2	0.008333	1.521118	23.32098	12.14813	62.78857	0.221204
3	0.008426	1.810890	23.05316	13.28798	61.43007	0.417899
4	0.008967	1.637032	27.02991	12.41484	58.54840	0.369818
5	0.009396	3.190030	27.02976	11.50157	56.31290	1.965742
6	0.009432	3.191640	27.02314	11.49632	56.10587	2.183031
7	0.009531	3.136793	27.41183	11.33776	55.94890	2.164710
8	0.009650	3.397050	27.70555	11.12572	55.21870	2.552974
9	0.009683	3.464206	27.80545	11.05000	54.88624	2.794101
10	0.009728	3.473916	28.09431	10.96465	54.62375	2.843378

Variance Decomposition of D(LOGREP):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.058008	0.026443	7.102877	6.460389	1.438144	84.97215
2	0.060568	0.120673	9.727724	6.000010	3.936877	80.21472
3	0.060991	0.322768	9.618548	5.958735	4.670382	79.42957
4	0.061828	0.346080	10.05128	6.882259	4.795061	77.92532
5	0.062098	0.460673	9.990925	6.844743	5.292284	77.41138
6	0.062498	0.596933	9.881544	6.861160	5.738029	76.92233
7	0.062583	0.639884	9.855334	6.857000	5.897566	76.75022
8	0.062738	0.727738	9.823910	6.869668	6.071868	76.50682
9	0.062852	0.729872	9.832765	6.860814	6.336908	76.23964
10	0.062894	0.733425	9.831015	6.904100	6.392457	76.13900

Cholesky Ordering: D(LOGRGDP) INF D(I) D(LOGRHP) D(LOGREP)

Figure 11: Impulse responses to orthogonalized one S.D. innovations in a two-standard-error confidence band. JAPAN

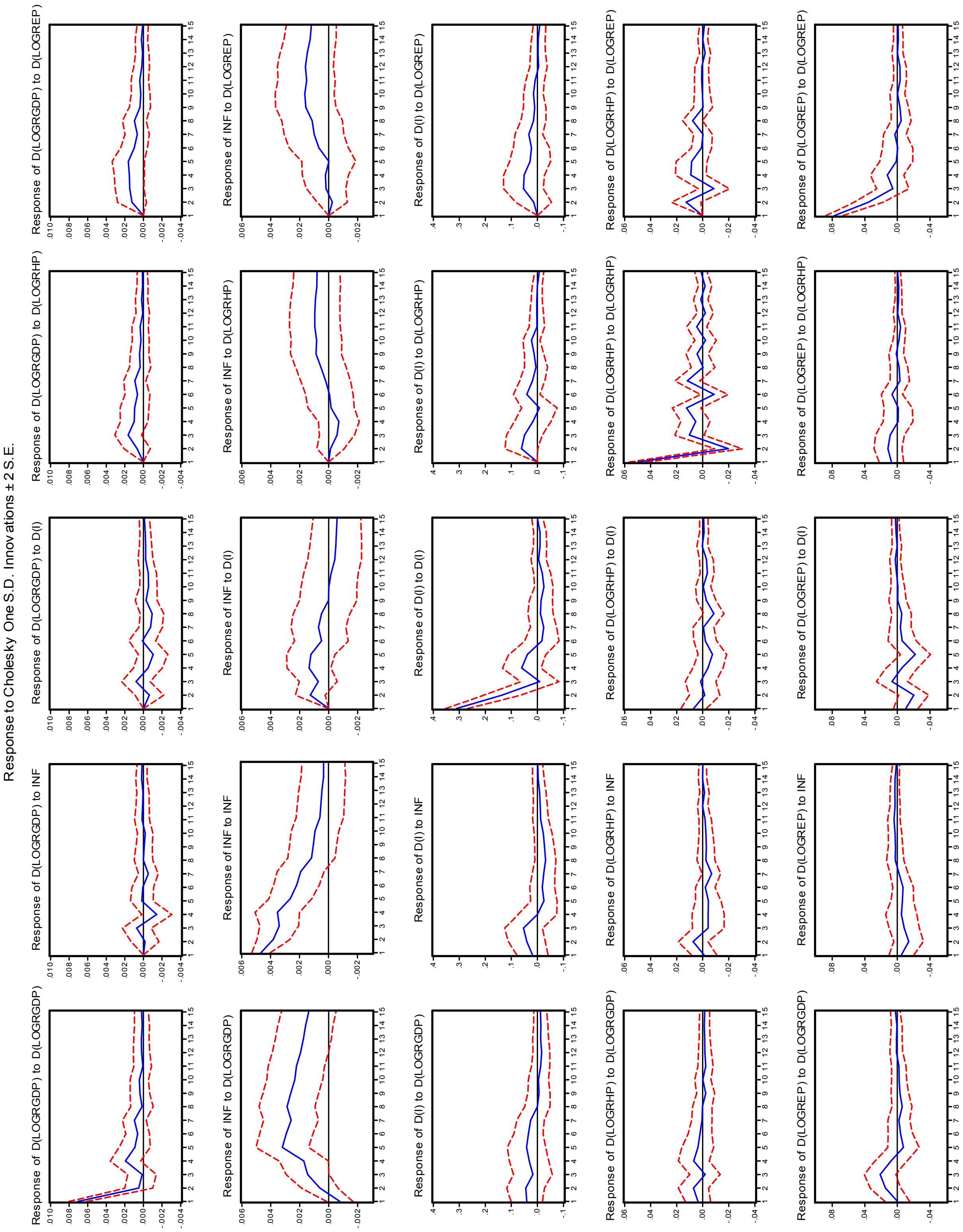


Figure 12 Variance Decomposition of the variables using Cholesky Decomposition for JAPAN

Variance Decomposition of D(LOGRGDP):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.007052	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.007239	95.38995	0.054545	0.762798	0.871167	2.921538
3	0.007649	85.46795	0.939832	1.787070	5.432269	6.372881
4	0.008230	79.29644	3.808313	1.900836	6.116031	8.878378
5	0.008560	74.47160	3.562022	3.239581	6.897541	11.82926
6	0.008665	73.17411	3.482497	3.181273	7.284256	12.87787
7	0.008843	71.47387	3.700901	3.814772	8.075199	12.93526
8	0.008953	69.74892	3.609866	4.801042	8.041639	13.79853
9	0.008984	69.45520	3.592470	4.870635	8.201596	13.88009
10	0.009022	69.11853	3.606760	5.189959	8.222605	13.86215

Variance Decomposition of INF:						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.004730	2.685287	97.31471	0.000000	0.000000	0.000000
2	0.006233	2.507144	93.19461	4.091527	0.046418	0.160298
3	0.007305	5.769722	89.44583	3.947573	0.660218	0.176658
4	0.008435	8.458975	84.57798	5.552566	1.203478	0.207000
5	0.009477	18.06465	74.70539	6.076846	0.988761	0.164351
6	0.010195	23.84841	69.22012	5.489235	0.858251	0.583976
7	0.010766	27.20949	65.24917	5.342600	0.806632	1.392109
8	0.011285	31.23569	60.46830	5.048850	0.954794	2.292373
9	0.011770	33.65494	56.38342	4.641847	1.426912	3.892876
10	0.012177	35.14022	53.24729	4.336804	1.791548	5.484138

Variance Decomposition of D(I):						
Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.313359	1.668990	0.360893	97.97012	0.000000	0.000000
2	0.352176	2.940702	1.613361	92.31059	2.973597	0.161746
3	0.363914	2.973251	3.618975	86.50999	4.600308	2.297480
4	0.374037	3.524977	3.425742	84.45497	4.571417	4.022889
5	0.380202	4.612772	3.749834	82.73543	4.467491	4.434473
6	0.385370	5.270590	3.887389	80.73411	5.447853	4.660056
7	0.389579	5.606638	4.188836	79.38187	5.564835	5.257823
8	0.391351	5.556016	4.790836	78.76037	5.532348	5.360432
9	0.392955	5.539414	5.244883	78.24306	5.586768	5.385876
10	0.395349	5.484697	5.510713	77.69792	5.846934	5.459737

Variance Decomposition of D(LOGRHP):

Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.050348	0.539362	0.044441	1.902231	97.51397	0.000000
2	0.056499	1.986880	1.721473	1.582179	89.67671	5.032758
3	0.058247	1.964481	2.146974	1.564666	87.42152	6.902359
4	0.059892	3.185912	2.532517	1.948743	83.50834	8.824489
5	0.062458	3.283034	2.800883	3.224710	80.75096	9.940412
6	0.063175	3.319697	2.839936	3.244091	80.85832	9.737959
7	0.064621	3.180368	3.816565	3.107767	80.58567	9.309631
8	0.065706	3.077211	3.831630	4.736768	77.94870	10.40569
9	0.066003	3.168205	3.981120	4.869509	77.66761	10.31355
10	0.066089	3.160521	4.112197	4.859770	77.57909	10.28843

Variance Decomposition of D(LOGREP):

Period	S.E.	D(LOGRGDP)	INF	D(I)	D(LOGRHP)	D(LOGREP)
1	0.078556	0.000440	0.406355	1.781014	0.863094	96.94910
2	0.091542	2.552604	2.605462	6.205893	2.211404	86.42464
3	0.095134	7.293811	3.212253	6.233028	2.902697	80.35821
4	0.096533	7.723315	3.374393	6.380162	2.829224	79.69291
5	0.099513	7.826104	3.558267	10.92898	2.676409	75.01024
6	0.100238	7.869489	4.002416	11.12602	3.071048	73.93103
7	0.100446	7.870297	4.036057	11.22323	3.153618	73.71680
8	0.100931	8.137776	4.067278	11.40143	3.165901	73.22761
9	0.101064	8.215275	4.106117	11.37293	3.173144	73.13253
10	0.101148	8.250360	4.172604	11.36033	3.204767	73.01194

Cholesky Ordering: D(LOGRGDP) INF D(I) D(LOGRHP) D(LOGREP)

Figure 13a: Robustness check using a different Cholesky ordering of the variables. Canada

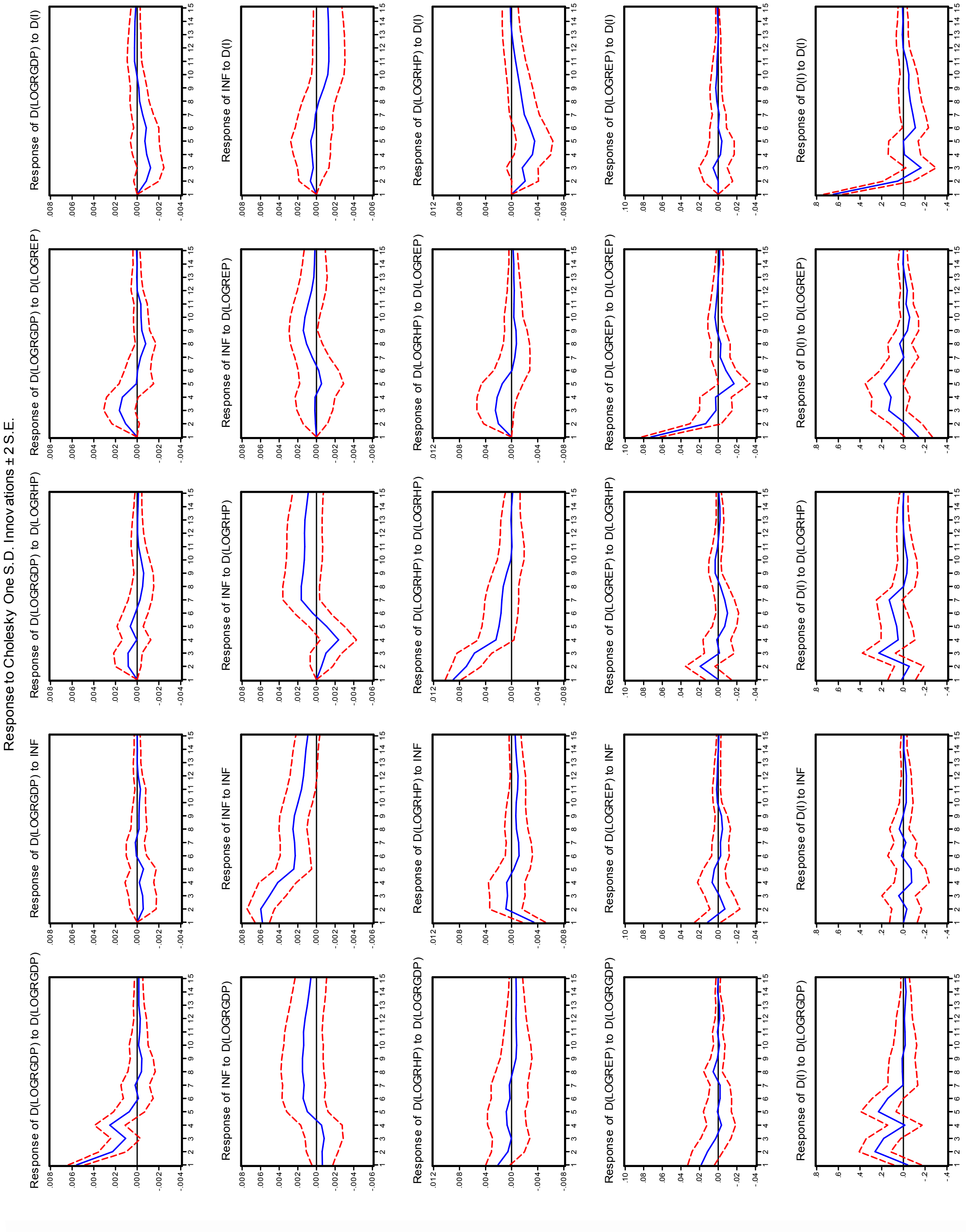


Figure 13b: Robustness check using a different Cholesky ordering of the variables. USA

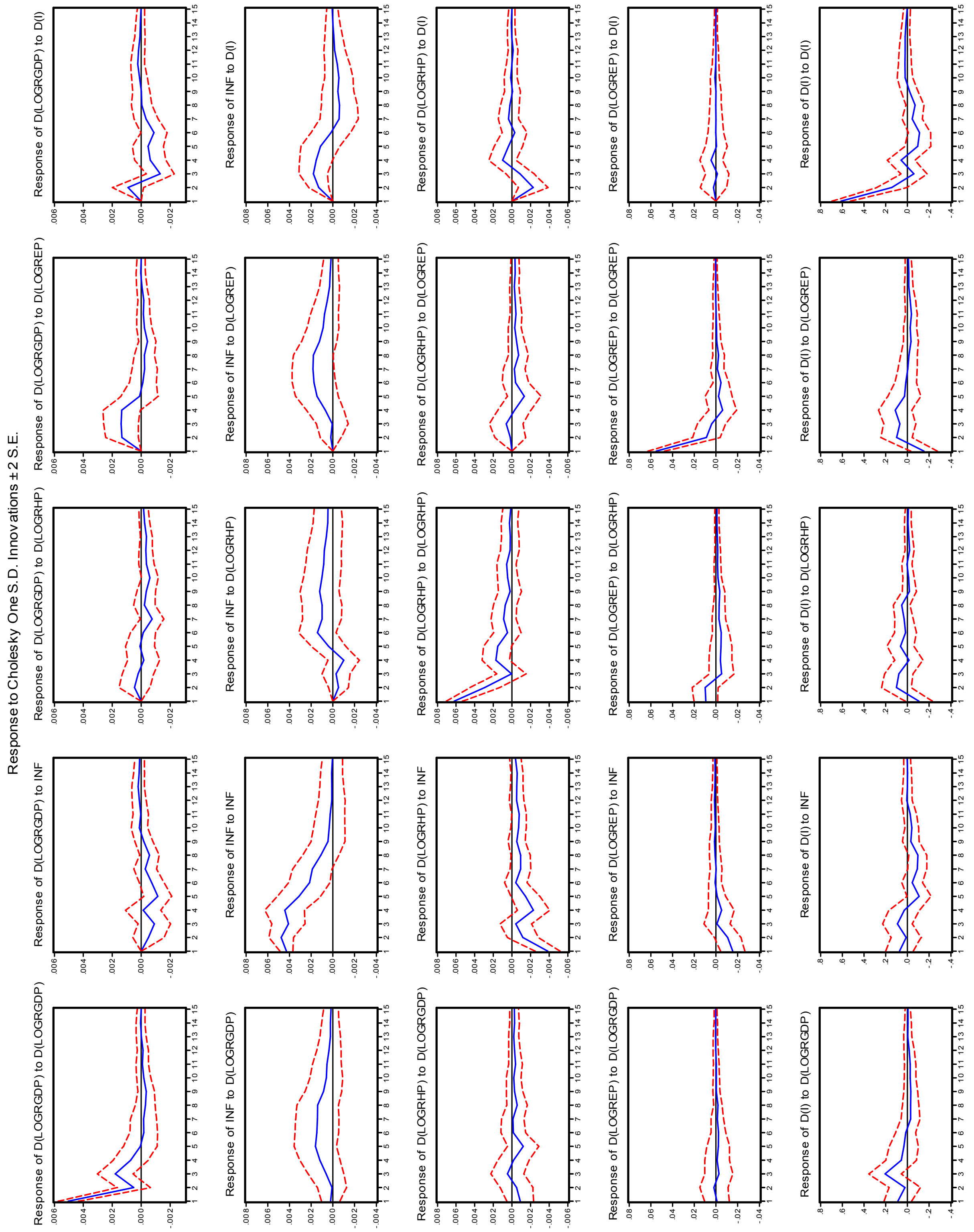


Figure 13c: Robustness check using a different Cholesky ordering of the variables. Japan