The Effectiveness of Monetary Policy: Empirical Evidence from a Non-Standard Identification Criterion

Luca Gambetti*

Universitat Pompeu Fabra

June 2000

Abstract

We apply VAR analysis in order to study the effects of a contractionary monetary policy shock on a set of real variables. The monetary policy shock is the one having (i) zero impact effect on real GDP and prices; (ii) a large impact effect of opposite sign on non-borrowed reserves and federal funds rate. This definition provides a set of *partial identifying* conditions applied to monthly and quarterly post-war US data. We find strong evidence in favor of short medium run *non-neutrality*. Our findings show that all the main real aggregates sharply reduce after a contractionary shock and such effects last approximately 7-8 years.

JEL Classification: E50, E52

Keywords: Monetary Policy Shock, VAR Analysis, Business Cycles, Real Sector.

*I would like to give special thanks to Mario Forni, Andrea Ginzburg, Barbara Pistoresi and Antonio Ribba for useful comments and conversations on issues discussed in this paper.

1 Introduction

The purpose of this paper is to provide new empirical evidence on the real effects of monetary policy by means of VAR analysis. We investigate the dynamic effects that monetary policy shocks generate on a broad set of real macroeconomic variables. Money neutrality has represented the core of the Keynesian-Classical debate since 1936, and has received much attention from economists throughout the century. Nowadays the debate is more silent, since there seems to be a growing agreement between economists on the role and the importance of monetary policy in actual economy. Although the opinion is far from uniform, most economists seem to believe that monetary policy can affect the level of real economic activity in the short run. Different beliefs remain about the mechanisms through which monetary policy generates such short run effects. Two different mechanisms are essentially invoked. First, agents expectations surprises due to unanticipated monetary policy actions (Lucas, 1972, Sargent and Wallace, 1976) which essentially leave no ground for systematic monetary policy reducing its importance as a tool for handling and correcting the economy. Second, price or wage rigidities (see Akerloff and Yellen, 1985, Ball and Romer, 1991, Blanchard, 1989, Fisher 1977, Mankiw, 1985, Taylor, 1979, 1980 and 1999 for a survey) which enable monetary policy to affect real economy in the short run. Another source of differences between economists involves the magnitude of such effects, emerging from empirical evidence. Some of them believe that the short run effects are very large, (Bernanke Mihov, 1998a, 1998b, Canova and De Nicolo, 2000) while other see these effects as rather small and inconsequential (Kim, 1999, Leeper Sims and Zha,1996, Sims and Zha, 1998, Uhlig, 1999). As for how the long run is concerned, the agreement is wider. Monetary policy is neutral, unable to generate real effects. This, essentially, because of the adjustment mechanism of expectations or prices which offsets monetary policy actions and move the system back to its previous long run path.

In the last two decades a huge amount of empirical literature on the real effects of monetary policy has been provided. Starting from the original contribution by Sims (1980), VAR analysis has been widely used in empirical macroeconomics (see Canova, 1995, for a survey). The basic idea of VAR models is the propagation impulse mechanism of Slutsky (1937) and Frisch (1933) formalized by the Wold Representation Theorem. By means of VAR analysis it is possible to separate the effects of any single shock over different time horizons. Recently there have been numerous contributions aiming to recover the effects of monetary policy by means of structural VAR analysis (see Christiano, Eichenbaum and Evans, 1998 for an exhaustive survey). In particular, much attention has been paid to identification procedures and several improvements have been provided. First, the *partial identification* of the model, just a subset of shocks can be identified and not the whole model (see Bernanke and Mihov, 1998). Second, the use of *non-standard* restrictions, sign restrictions, maximization conditions and quasi-identification conditions (see Canova and De Nicolo', 2000, Gambetti, 1999, Faust, 1998, and Uhlig, 1999).

In this paper we apply the criterion provided in Gambetti (1999) to study the dynamic responses of several real variables to a monetary policy shock. Such a criterion involves a *partial identification* scheme based on hypotheses concerning the shock impact effect on *non-policy* variable (real variables and prices) and *policy* variable (non-borrowed reserves and federal funds rate), prices, non-borrowed reserves and the federal funds rate. No restrictions are imposed on the long run behavior. The monetary policy shock is the one having a (i) zero impact effect on real GDP and prices and a (ii) large effect of opposite sign on non-borrowed reserves and the federal funds rate, according to the theory of the liquidity effect. While the first hypothesis constraints real GDP and prices impact effects to be zero, the second involves non-standard restrictions. Such restrictions are imposed by means of a joint constrained maximization of the impact effects on non-borrowed reserves and the federal funds rate.

We apply such a criterion to several differently specified VAR models. All these specifications contain a common set of variables: the industrial production index (IPI), the consumer prices index (CPI), a commodities price index (PC), the ratio non-borrowed reserves total reserves (NBRX) and the federal fund rate (FFR). The specifications differ each other for a further real variable included in the model. Precisely we estimate 6 different VAR including unemployment, real wages, real profits, productivity (output per hours), consumption and private fixed investments. We find srong evidence in favor of money non-neutrality. The shock leads to a persistent and long lasting decline in all the real aggregates considered. Results show that the monetary policy shock largely affects the level of real activity and its effcts last approximately 7-8 years. Moreover we investigate the channels through which monetary policy acts. The candidates are essentially the long term real interest rate, bank loans and the real exchange rate. Results show that all these channels are important for the transmission of monetary policy actions to real economy.

The paper is organized as follows. Section 2 describes the econometric tools focusing on representation and identification. Section 3 resumes the results about real aggregates (3.1) and the transmission channels (3.2). Section 4 draws the conclusions.

2 The Model

This section is devoted to the empirical model applied for the analysis, focusing on the representation theory and the identification criterion.

2.1 Representation

Let X_t be a covariance stationary stochastic vector process[1]; from the Wold Decomposition Theorem we may represent X_t in terms of innovations

$$X_t = A(L)\varepsilon_t \tag{1}$$

where $A(L) = I + A_1 L + A_2 L^2 + ...$ is a matrix of polynomials in the lag operator L and ε_t is a zero mean white noise vector process with variance $E\varepsilon_t\varepsilon_t' = \Sigma_\varepsilon$ and $E\varepsilon_t\varepsilon_{t-k}' = 0$ for $k \neq 0$. Let S be the Choleski factor of Σ_ε and H any matrix such that $HH' = I$. By postmultiplying $A(L)$ for SH and premulitiplying ε_t for $H'S^{-1}$ we obtain the orthonormal representation

$$X_t = C(L)e_t \tag{2}$$

where

$$C(L) = A(L)SH \tag{3}$$

$e_t = H'S^{-1}\varepsilon_t$, $Ee_te_t' = I$ and $C(0) = SH$. Equation (2) is the VAR structural form. The matrix $C(L)$ contains the effects of the structural shocks on the vector X_t. Our purpose is to identify just the monetary policy shock leaving other shocks unidentified. Then we can partition the model as follows: $H = (H_1|H_2)$, $C(L) = (C_1(L)|C_2(L))$ and $e_t' = (e_{1t}'|e_{2t}')$. Equation (2) can be rewritten as

$$X_t = A(L)SH_1H_1'\eta_t + A(L)SH_2H_2'\eta_t = C_1(L)e_{1t} + C_2(L)e_{2t} \tag{4}$$

where $C_1(L) = A(L)SH_1$, $C_2(L) = A(L)SH_2$, $e_{1t} = H_1'\eta_t$[2] and $e_{2t} = H_2'\eta_t$; e_{1t} is the monetary policy shock and $C_1(L)$ the relative impulses, H_1 is the column we must choose for identifying. $C_2(L)e_{2t}$ is the model relative to the other $(n-m)$ shocks.

[1]See Appendix A for details.
[2]See Appendix A for the definition of η_t.

2.2 Identification

Consider equation (4). Our purpose is to determine H_1 in order to recover the structural form $C_1(L)$. The vector X_t includes the following variable: the Industrial Production Index (IPI), an additional real variable (RV), the Consumer Price Index (CPI), two policy variables, the ratio of non-borrowed reserves and total reserves (NBRX)[3], and the federal funds rate (FFR), and a index for the price of commodities (PC)[4][5]. The orthonormality condition provides us with 1 restrictions; since the number of free parameters is n, in order to fix H_1 we need $(n-1)$ further restrictions. Such restrictions are derived from two sets of identifying assumptions: a set of macroeconomic assumptions and a set of assumption involving the operating mechanism of the market for bank reserves. We assume

(i) The real economy reacts to the monetary policy shock with a period of lag. This implies two contemporaneous restrictions on the industrial production index and on the other real variable of interest.

(ii) Prices are sticky, the CPI reacts to monetary policy actions with a period of lag.

(iii) A contractionary monetary policy shock has a negative impact effect on non-borrowed reserves.

(iv) A contractionary monetary policy shock has a positive impact effect on the federal funds rate.

(v) The impact effects in *iii* and *iv* are both large.

Hypotheses (i) and (ii) are widely used in VAR literature (see e.g Bernanke and Blinder, 1992, Strongin, 1995 and Bernanke and Mihov, 1998a 1998b).

[3]Follwing the suggestion of Strongin (1995) we use that ratio rather than the non-borrowed reserves, since an exogenous monetary policy shock leave the total reserves unchanged because of the inelasticity of the short run reserves demand curve. The commercial banks shift the borrowing from the market to the fed and the level overall amount of reserves does not change in the very short period.

[4]The prices of commodities are included in order to avoid the well known *price puzzle* resulting from the bad specification of the model, see Christiano.

[5]We use both monthly and quarterly data, the sample period spans from January 1959 to march 2000. All the variables are taken in level and in logarithms except for NBRX and FFR. For monthly observations we include 12 lags in the VAR, for quarterly observations 4 lags.

Assumption *(i)* refers to the lag in the transmission of monetary policy actions to real economy. Assumption on CPI is derived from sticky price models (see e.g. Fisher, 1977, and Taylor, 1998, for a survey).

Assumption (*iii*) and (*iv*) derive from the theory of the liquidity effect: for a given reserves demand, a change in non-borrowed reserves produces, in the short term, a change of opposite sign on nominal interest rate (see e.g. Cagan and Gandolfi, 1968, Leeper and Gordon, 1992, Christiano, Eichenbaum and Evans, 1992, Pagan and Robertson, 1995, Strongin, 1995, Bernanke and Mihov, 1998b).

Assumption (v) states that the portion of variances of FFR and NBR explained by the monetary policy shock within the first month is large[6]. That assumption is justified since FFR and NBR are under the Fed control and there are no lag in the transmission of monetary policy actions to these variable.

In order to identify we use the same procedure provided in Gambetti (1999). From equation (4) we define $C_{1,0}$ the **impact vector** of the monetary policy shock. Denoting c_i the i^{th} element of C_1, and h_i the i^{th} element of H_1, from hypotheses i and ii we have $c_1 = c_2 = c_3 = 0$; since $c_1 = s_{11}h_1$, $c_2 = s_{21}h_1 + s_{22}h_2$ and $s_{21}h_1 + s_{22}h_2 + s_{23}h_3$ this implies $h_1 = h_2 = h_3 = 0$. Hypothesis iii involves $c_4 < 0$ and hypothesis iv $c_5 > 0$. Hypothesis v, by assuming that c_4 and c_5 are large, provides us with a constrained maximization restriction. Let us define $\theta_1 = c_{41}^2/\sigma_{NBR}^2$ and $\theta_2 = c_{51}^2/\sigma_{FFR}^2$[7]. In order to have an idea of the maximal size of the impact effect of the shock on FFR and NBR let us maximize separately θ_1 and θ_2. Let $\Theta_1 = max(\theta_1)$ and $\Theta_2 = max(\theta_2)$[8]. Θ_1, Θ_2 signify the largest contribution possible of the monetary policy shock in the first month to the

[6]Since $Ee_t e'_{t-k} = 0$ for $k \neq 0$ the variance of the i^th element x_i of the vector X_t will be

$$var(x_{it}) = \sigma_{x_i}^2 = \sum_{j=1}^{6}\sum_{k=0}^{\infty} \mathrm{var}(e_j)c_{ijk}^2 \tag{5}$$

with $i = 1, ..., n$, $j = 1, ..., n$ and k the time horizon; since $var(e_j) = 1$

$$var(x_{it}) = \sum_{j=1}^{6}\sum_{k=0}^{\infty} c_{ijk}^2. \tag{6}$$

By assuming that c_{ij0} is large, we assume that the contribution of the j^{th} shock to the variance of the i^{th} variable in $k = 0$ is large

[7]We normalize the coefficients for the standard deviations of the first differences of the series.

[8]The only constraint is $\sum_{i=1}^{n} h_i^2 = 1$; $\Theta_1 = max(\theta_1)$ for $h_4^2 = 1$ and $\Theta_2 = max(\theta_2)$ for $h_4^2 + h_5^2 = 1$

variances of the two series FFR and NBR (see note).

In order to keep the impact effects jointly large, we proceed as follows: first, we calculate the ratio $r = \Theta_1/\Theta_2$ and second we maximize θ_1 under the constraints $\theta_1/\theta_2 = r$. In such a way we obtain the constrained maximal values $\bar{\Theta}_1$ and $\bar{\Theta}_2$. From $\bar{\Theta}_1$, $\bar{\Theta}_2$ and from the sign constraints (iii) $c_4 < 0$ and (iv) $c_5 > 0$, it is possible to derive the impact coefficients $\hat{c}_4$ and $\hat{c}_5$. The constrained maximization implies two restrictions, on h_4 and h_5 (see Appendix B). From the hypothesis of orthonormality of the matrix H, the following condition must hold, $\sum_{i=1}^{n} h_i^2 = 1$; such a condition implies a restriction on h_6 which determines $\hat{c}_6$ and identifies $C_1(L)$ (see Appendix B).
The **monetary policy impact vector**, $C_{1,0}$, is .

$$C_{1,0} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ \hat{c}_4 \\ \hat{c}_5 \\ \hat{c}_6 \end{pmatrix} \tag{7}$$

3 Empirical Evidence

The main consequences on non-real variables of a contractionary monetary policy shock are are the following. First, the CPI reacts very sluggishly and begins to drop only after 18-months. This suggests a high degree of price stickiness. Although the reduction in the price level is permanent, we do not find strong evidence for the monetary contraction to succeed in reducing inflation significantly. In the very first months the dynamic of inflation is ambiguous, very close to zero with two positive peaks. After 18-months, inflation drops but the reduction is modest and weak. Second, non-borrowed reserves initially drop (reaching a maximal reduction of about 0.6-percent) than from one to two years they reverse to the preshock value. Third, the federal funds rate reacts positively reaching its maximum (an increase of 0.7-percent)during the second month, than reverses to the initial value within the year.

3.1 Real Aggregates

Findings show wide and long-lasting effects, providing evidence against money neutrality in the short medium run. A contractionary monetary policy shock produces a slow down of the real economy wich lasts approximately 7-8-years. Figure 1 displays the rsponse of the Industrial Production Index. Industrial production falls significantly declining for five years. From the fifth year the effect of the shock on real GDP reduces, although not completely vanishing. Figure 2 displays the effect of a contractionary monetary policy shock on unemployment. After an initial lag, the unemployment rate rises, reaching its maximum level after 20-months (an increase of about 0.4-percent). It remains at that level for 7-8 months than reverts back to its pre-shock value. The effect of the contraction on unemployment is quantitatively large and long lasting.

Figure 3 reports the response of real wages (solid line) profits (dashed line) and productivity (dotted line). Real wages reduce sharply declining for 10-quarters. At the end of the third year real wages are 0.6-percent less than the pre-shock value. From the fourth year the response of real wages reverses and the effect of the shock reduces. In the long run real wages remain steadly below (0.2-percent less) the preshock value. Also profits reduce after the shock, but the response is quantitatively smaller than that of real wages and the dynamic is less persistent. For the first year their response is identical to that of real wages. At the end of the first year profits reach its minimum level (about 0.3-percent less than the pre-shock level). They remain one year at that level, than reverse and they converge to its initial level within the third year. After a contractionary policy shock both profits and real wages fall. But while the former are back to the preshock value after the third year, the second show a permanet reduction of 0.2-percent. Such a result implies a sort of income redistribution from the workers to the owners, the former suffering more the effects of the contraction.

Productivity drops abruptly after the shock reaching its minimum after the first year (a reduction of 0.3-percent). From the second year the effect of the shock reduces but it remains steadly below its initial level. The monetary contraction leads to a sharp and immediate fall in labor productivity, measured as output per hours[9] which more than offsets the fall in real wages and causes the profits to reduce. One possible explanation refers to unmeasured variations in labor effort. If labor effort and worked hours move in the same direction, the contraction leads to a reduction of worked hours (a reduction of the number of employed) together with a fall in the labor effort. Productivity of labor will fall. For a substantial drop in labor productivity, the benefits for firms deriving from the reduction of real wages are offset and profits may fall. Indeed our findings

[9]Productivity, measured as output per employed, should fall more sharply since the contraction is expected to affect, at least in the first months, more the number of hours worked than the number of employed.

show that, in the very first months, productivity falls more sharply than real wages and this leads to a fall in profits. As producivity stops falling while real wages do not, profits revert back upto the preshock level.

Figure 4 shows the response of fixed private investments to the monetary contraction. Investments react immediatly to the shock and for the first three years they reduce sharply. At the end of the third year they reach its minimum level, a reduction of almost 1-percent, then the effects begins to reduce, although keeping investments steadly below the initial level. The drop in investments lasts ten years. Investemnts are highly affected by the contraction and is the factor which contributes mainly to the reduction of the overall real activity. As we will argue in the next subsection, the channel trough which monetary policy affects investments are essentially the long run real interest rate and the bank loans.

Figure 5 displays the impulse response function for real personal consumption expenditure. Consumption is strongly affected by the monetary contraction. After 12-months consumption reaches its minimum level, a reduction of 0.6-percent, and remains very close to that level for the three years after. From the fourth year the effect begins to reduce vanishing in the long run. Such a result is quite puzzling since we should expect less variability of consumption with respect to output, while the response of the two aggregates is quantitatively similar. A plausible explanation is that real personal consumption includes consumption for durables and this would cause variability in aggregate consumption.

Figure 6 shows the dynamic response of real imports end real exports of goods and services and the trade balance (Figure 7). Both imports and exports drop after the shock. Exports reach the minimum level during the second year after the shock (a reduction of about 0.5-percent) and converge to its initial level after five years. Imports reaches the minimum during the first year (a reduction of about 0.7-percent) and return to the initial level after four years. The year of delay between the two dynamics is shown in the trade balance. The short run response of the trade balance display two different effects, the first due to the demand reduction, the second, as we will show in the next subsection, due to the dollar appreciation. Initially the balance improves since imports fall more sharply than exports because of the aggregate demand reduction. As dollar begins to appreciate, exports reduce more than imports and the trade balance whorsens. The second effect dominates the former in the medium run since the balance remains steadly negative for about 6-years. In the long run the balance reverts to the preshock value, being unaffected by the contraction essentially because the exchange rate tends to its initial level.

3.2 The Transmission Channels

In this section we discuss the evidence regarding the transmission channels through which moneatary policy affect real economy. The candidates channels for monetary transmission are essentially three: monetary channel (interest rate), the credit channel (lending activities) and the exchange rate channel. The first essentially operates through investments, high interest rates depress investments. The second operates through investments and consumption. The presence of rigidities and frictions in the banking system can affect economy since the amount of loans to families and companies can be limited by factors other than interest rate. The latter operates through imports and exports.

Figure 9 displays the response of the long term real interest rate. The real rate immediately increases, and this because of the price rigidities which keep inflation constant in the first months after the shock. For about 30-months the real rate raises upto an increase of 0.3-percent. Only after 3-years real rate begin to reduce but it takes more than 5-years to reach its initial level. The long term real interest rate shows a very long lasting dynamic. The monetary channel is important for the transmission of monetary policy action. This explain why investments drop so much. An increase in the federal funds rate raises the long run rate which, given the small reduction of inflation, highly depress investments and the level of real activity.

Figure 8 displays the dynamic effects of a monetary contraction on consumer loans (solid) and commercial and industrial loans (dashed line). Policy actions affect commercial banks loans. The consumers loans reduce fastly reaching the minimum level during the second year, than reversing and returning to the initial level at the end of the third year. The dynamic of industrial loans is slower and the effect of the shock is more persistent. After an initial lag, commercial and industrial loans begin to drop reaching the minimum level at the end of the fourth year. This means that while consumers loans are back to the preshock value, commercial and industrial loans are at their minimum (0.6-percent less). After the fourth year they reverse course, the effect decreasing, but remain below the initial level until the seventh year after the shock. The effect of the monetary policy shock on bank loans is crucial since provide evidence in favor of the credit channel which amplifies, beside the monetary channel, the real effect of monetary actions. Even the credit channel matter. The contraction leads to a sharp fall in commercial banks loans which lasts for long time. If market and bank loans are not perfect substitutes, which is plausible mainly for small firms, the reduction in the amount of disposable loans amplifies the effects of policy actions and modifies the dynamics of investments.

Figure 10 shows the dynamic response of the real exchange rate to the contraction. From the second month the exchange rate appreciate reaching its maximum value at the end of the second year. Than the effect reduces but the exchange rate remains above the preshock value. Such finding is explained by the rise in the federal funds rate which attracts foreign capitals making the dollar appreciate. This enatails important consequences on the trade balance. Actually the dollar appreciation reducing exports whorsens the trade balance, since such effects prevail on the demand reduction effect which reduces imports.

4 Conclusions

In this paper we aplly an innovative identification criterion in order to recover the effects that monetary policy produces on a broad set of real aggregates. Such a criterion is based on a set of partial identifying assumptions which provide non standard restrictions to be applied to the VAR. Such restrictions involve the sign and the size of the impact effect of real GDP, prices, federal funds rate and non-borrowed reserves. Findings provide empirical evidence in favor of short medium run non-neutrality, since all the principal real aggregates are affected by the shock and such effects last 7-8 years. Monetary policy, however, althought powerful in the short medium run is neutral in the long run. Indeed the economy in the long run converge to its initial long run equilibrium. Our conclusion is in line with many previous works which stress the importance of the monetary policy as a useful and powerful tool to handle and correct real economy in the short medium run.

References

Akerloff, G and Yellen, J.L. (1985) "Can Small Deviations from Rationality Make Significant Differences to Economic Equilibria?" *Quarterly Journal of Economics* 84 (august):488-500

Ball, L. and Romer, D. (1991) "Stcky Prices as Coordination Failure." *American Economic Reviwe* 81: 539-552.

Bernanke, B and Blinder, A (1992) "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review*, 82 (September): 901-921.

Bernanke, B. and Mihov, I (1998a) "Measuring Monetary Policy." *Quarterly Journal of Economics* 113: 869-902.

Bernanke, B. and Mihov, I. (1998b) "The Liquidity Effect and the Long-Run Neutrality." *Carnegie-Rochester Conference Series on Public Policy*, 49: 149-194.

Blanchard, O. (1984) "Price Asynchronisation and the Price Level Inertia." in Dornbush, R. and Simonsen, M. H. (ed.) *Inflation, Debt and Indexation.* Cambridge MA: The MIT Press.

Cagan, P. and Gandolfi, A. (1969) "The Lag in Monetary Policy as Implied by the Time Pattern of Monetary Effects on Interest Rate," *American Economic Review*, Papers and Proceedings, 59 (February): 191-205.

Canova, F. (1995) "The Economics of VAR Models." in Hoover, K. *Macroeconometrics*, Boston: Kluwer Academic Publisher.

Canova, F. and De Nicolo', G. (2000) "Monetary Disturbances Matter for Business Fluctuation in the G-7", Boards of Governors of the Federal Reserve System,*International Finance Discussion Paper*, No. 660 (February).

Christiano, L. and Eichenbaum, M. (1992) "Identification and the Liquidity Effect of a Monetary Policy Shock," in Cukierman, A. Hercovitz, Z. e Leiderman, L. (ed.) *Political Economy, Growth, and Business Cycles.* Cambridge MA: The MIT Press.

Christiano, L. Eichenbaum, M. and Evans, C. (1998) "Monetary Policy Shocks: What We Have Learned and to What End?" *NBER Working Papers*, No. 6400.

Faust, J. (1998) "On the Robusteness of the Identified VAR Conclusions About Money." *Carnegie Rochester Conference Series on Public Policy*, 49: 207-244.

Fisher, S. (1977) "Long Term Contracts, Rational Expectations, and the Optimal Money Supply Rule." *Journal of Political Economy*, 85: 163-190.

Frisch, R. (1933) "Propagation Problems and Impulse Problems in Dynamic Economics." in *Economic Essays in Honor of Gustav Cassel*. London: Allen and Unwin.

Gambetti, L. (1999) "The Real Effects of Monetary Policy: A New Identification Procedure." *Rivista di Politica Economica*, No. XII: 149-169.

Kim, S. (1999) "Do Monetary Policy Shock Matter in the G-7 Countries? Using Common Identifying Assumption about Monetary Policy Across Countries" *Journal of International Economics*, 48: 387-412.

Leeper, E. and Gordon, D. (1992) "In Search of the Liquidity Effect." *Journal of Monetary Economics* 29 (June): 341-369.

Leeper, E. Sims, C and Zha.T (1996) "What Does Monetary Policy Do." *Brooking Paper on Economic Activity*, 1:1-75.

Lucas, R. (1972) "Expectations and the Neutrality of Money." *Journal of Economic Theory* 4: 104-124.

Mankiw, R. (1985) "Small Menu Cost and Large Business Cycles." *Quarterly Journal of Economics*, 101: 529-537.

Pagan, A. and Robertson, J. (1995) "Resolving the Liquidity Effect." *Federal Reserve Bank of St. Louis Review* 77 (May/June): 33-54.

Sargent, T.J. and Wallace, N. (1975) "Rational Expectations, the Optimal Monetary Instrument and the Optimal Money Supply Rule." *Journal of Political Economy*, 83: 241-254.

Sims, C. (1980) "Macroeconomics and Reality." *Econometrica* 48: 1-48.

Sims, C. and Zha, T. (1998) "Does Monetary Policy Generate Recessions?" Federal Reserve Bank of Atlanta, *Working Paper* No: 98.12.

Slutsky, E. (1937) "The Summation of Random Causes as the Source of Cyclical Process." *Econometrica* 5: 105-146.

Strongin, S (1995) "The Identification of Monetary Policy Disturbances: Explaining the Liquidity Puzzle." *Journal of Monetary Economics* 34: 463-497.

Taylor, J. (1980) "Aggregate Dynamics and Staggered Contracts." *Journal of Political Economy* 88: 1-23.

Taylor, J. (1998) "Staggered Contracts and Wage Setting in Macroeconomics." NBER *Working Papers Series* No. 6754.

Tobin, J. (1965) "Money and Economic Growth." *Econometrica*, 33: 671-684.

Uhlig, H. (1999) "What Are the Effects of Monetary Policy? Results from an Agnostic Identification Procedure." CEPR *Discussion Papers* No. 2137.

Appendix A

The building block of VAR econometrics is the Wold Representation Theorem that states that any stationary stochastic process can be decomposed in two orthogonal components in the following manner:

$$X_t = \sum_{j=0}^{\infty} \alpha_j \varepsilon_{t-j} + \mu_t \tag{8}$$

where $\sum_{j=0}^{\infty} \alpha_j \varepsilon_{t-j}$ represents the stochastic component, with $\sum_{j=0}^{\infty} \alpha_j^2 < \infty$, $\{\varepsilon_{t-j}\}_{j=0}^{\infty}$ is a zero mean white noise process, that is (a) $E\varepsilon_t\varepsilon_t' = \sum_\varepsilon$, $E\varepsilon_t\varepsilon_{t-k}' = 0$ for $k \neq 0$, and μ_t represents the purely deterministic component, the one perfectly predictable by using past information. As usual in VAR literature, we will consider only *regular process*, that is those processes for which $\mu_t = 0$. Rewriting (9) in lag operator terms and assuming $\mu_t = 0$ we have the representation (1). Equation (1) is the Wold representation of the process X_t and the following conditions hold: (a), (b) all the roots of the determinant of $A(L)$ are outside the unit circle in the complex field, (c) $A(0) = I$. Conditions (a), (b) and (c) guarantee the unicity of the representation. From the Wold representation is possible to derive the class of *fundamental*[10] representations of the process X_t. Given any non singular matrix of constants R is possible to rewrite (1) as follows

$$X_t = A(L)RR^{-1}\varepsilon_t = B(L)u_t \tag{9}$$

where $B(L) = A(L)R$ and $u_t = R^{-1}\varepsilon_t$. Since R can be any non-singular matrix of constants, it follows that the class of fundamental representations defined by (10) has infinite representations that differ from each other for a particular R. From the class of fundamental representations we may define a subclass, that of orthonormal representations. Let S be the Choleski factor of $\sum_\varepsilon$ such that $SS' = \Sigma\varepsilon$. Postmultiplying $A(L)$ for S and premultiplying ε_t for S^{-1} in (1) we obtain

$$X_t = D(L)\eta_t \tag{10}$$

where $D(L) = A(L)S$ and $\eta_t = S^{-1}\varepsilon_t$. Equation (11) is the Choleski representation of X_t and has the following properties: $D(0) = S$, $D(L) = S + D_1L + D_2L + ...$, $\sum_\eta = E\eta_t\eta_t' = S^{-1}\sum_\varepsilon S'^{-1} = I$. As for the class of fundamental representations, even in this case it is possible to generalize to the whole class of orthonormal representations. For any matrix H such that $HH' = I$, by

[10] The representations for which condition (b) holds.

postmultiplying $A(L)S$ for H and premultiplying η_t for H' we obtain the representation (2). Representation (1) has the same properties of representation (11) and differs from (11) for H. The class of orthonormal representations, as subclass of fundamentals, contains infinite representations which differ from each others for a particular choice of H.

Given a matrix H, equation (1) and (2) set up our model: the first is the reduced form and the second the structural form of the VAR. The following relations hold: $C(L) = A(L)SH$ and $e_t = H'S^-1\varepsilon_t$.

Appendix B

Here we show technical aspects of the identification criterion and we show how to choose the vector H_1. The first step consists in transforming the model expressed by equation (1) into the orthonormal model expressed by equation (11) by postmultiplying $A(L)$ by the Choleski factor S of the variance-covariance matrix $\sum_{\varepsilon}$. The second step consists in choosing the vector H_1 in order to determine $C_1(L)$ by postmultiplying $A(L)S$ for H_1. H_1 is obtained as follows. Let us consider the impact vector $C_1 = SH_1$. Hypotheses (i) and (ii) entail $s_{11}h_1 = 0$, $s_{21}h_1 + s_{22}h_2 = 0$ and $s_{31}h_1 + s_{32}h_2 + s_{33}h_3 = 0$; since S is lower triangular, $s_{ij} \neq 0$ for $i \geq j$, $h_1 = h_2 = h_3 = 0$. Hypotheses (iii) and (iv) involve $s_{44}h_4 < 0$ and $s_{54}h_4 + s_{55}h_5 > 0$. From hypothesis (v) $s_{44}h_4$ and $s_{54}h_4 + s_{55}h_5$ must be jointly large. Recall that[11] $\theta_1 = (s_{44}h_4)^2$ and $\theta_2 = (s_{54}h_4 + s_{55}h_5)^2$, $\Theta_1 = max(\theta_1) = (s_{44}h_4^*)^2$ and $\Theta_2 = max(\theta_2) = (s_{54}h_4^* + s_{55}h_5^*)^2$. First we calculate the ratio, $r = \Theta_1/\Theta_2$, then we maximize θ_1 under the constraints $\theta_1/\theta_2 = r$ and the sign constraints $s_{44}h_4 < 0$, $s_{54}h_4 + s_{55}h_5 > 0$. Hence we have $\frac{s_{44}h_4}{s_{54}h_4+s_{55}h_5} = -\sqrt{r}$ Easy arithmetic passages lead to

$$h_5 = h_4 \left(-\frac{s_{44} + \sqrt{r}s_{54}}{\sqrt{r}s_{55}} \right). \tag{11}$$

Let

$$\left(-\frac{s_{44} + \sqrt{r}s_{54}}{\sqrt{r}s_{55}} \right) = \Gamma. \tag{12}$$

From the orthonormality condition, $\sum_{i=1}^{n} h_i^2 = 1$, the following restriction must hold

$$h_6 = \pm\sqrt{1 - h_4^2 - h_5^2} = \pm\sqrt{1 - h_4^2 - h_4^2\Gamma^2} \tag{13}$$

From equation (12) and (14) we have

$$(1 + \Gamma^2)h_4^2 \leq 1 \tag{14}$$

Since s_{44} is constant, the impact effect on non-borrowed reserves will be maximum when h_4 is maximum, hence when h_4^2 is maximum, and we will have

$$h_4 = \pm\frac{1}{\sqrt{1 + \Gamma^2}} \tag{15}$$

[11] Here we assume, for convenience of exposition, that the elements s_{ij} of S have been divided by the standard deviation, σ_i, of first differences of the i^{th} element x_i.

In particular from (iii), since $s_{44} > 0$, see Table 2, h_4 must be negative. From equations (14) and (16) we have $h_6 = 0$; this last passage completes the identification. H_1 will result

$$H_1 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ -\frac{1}{\sqrt{1+\Gamma^2}} \\ -\frac{\Gamma}{\sqrt{1+\Gamma^2}} \\ 0 \end{pmatrix}, \tag{16}$$

$\bar{\Theta}_1 = \left(\frac{s_{44}}{\sqrt{1+\Gamma^2}}\right)^2$, $\bar{\Theta}_2 = \left(\frac{s_{54}+s_{55}\Gamma}{\sqrt{1+\Gamma^2}}\right)^2$, $\hat{c}_4 = -\frac{s_{44}}{\sqrt{1+\Gamma^2}}$ and $\hat{c}_5 = -\frac{s_{54}+s_{55}\Gamma}{\sqrt{1+\Gamma^2}}$, since $s_{54} < 0$, $s_{55} > 0$ and $\Gamma < 0$, see Table 2. The vector C_1 will be

$$C_1 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ -\frac{s_{44}}{\sqrt{1+\Gamma^2}} \\ -\frac{s_{54}+s_{55}\Gamma}{\sqrt{1+\Gamma^2}} \\ \frac{s_{65}\Gamma-s_{64}}{\sqrt{1+\Gamma^2}} \end{pmatrix}. \tag{17}$$

Figures

Figure 1

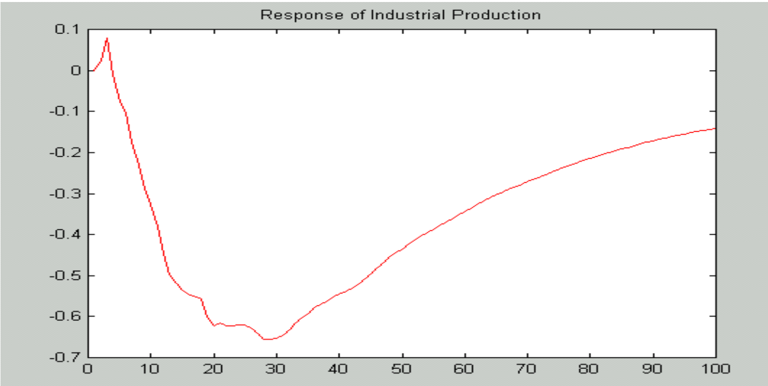

Figure 2

Figure 3

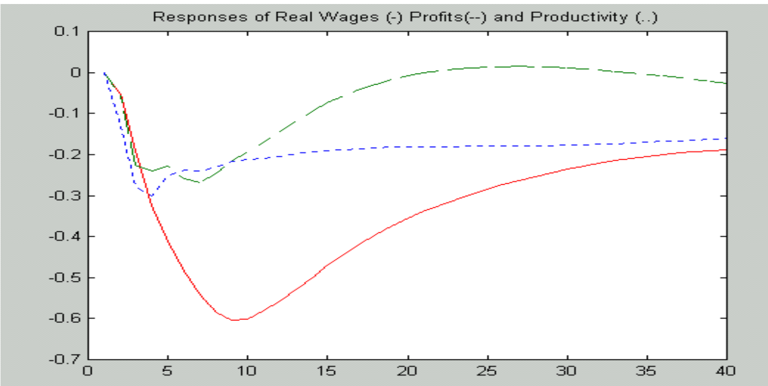

Figure 4

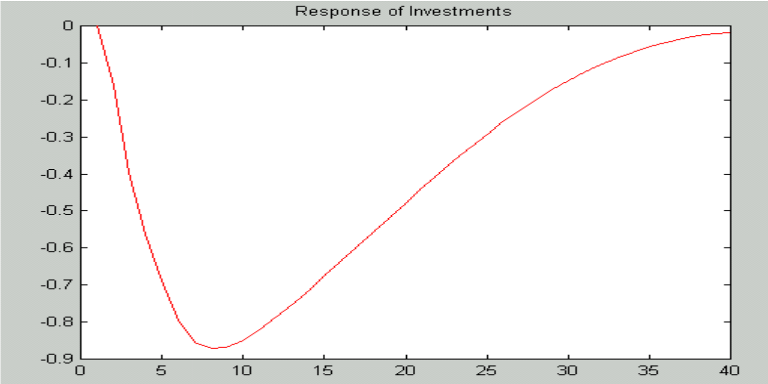

Figure 5

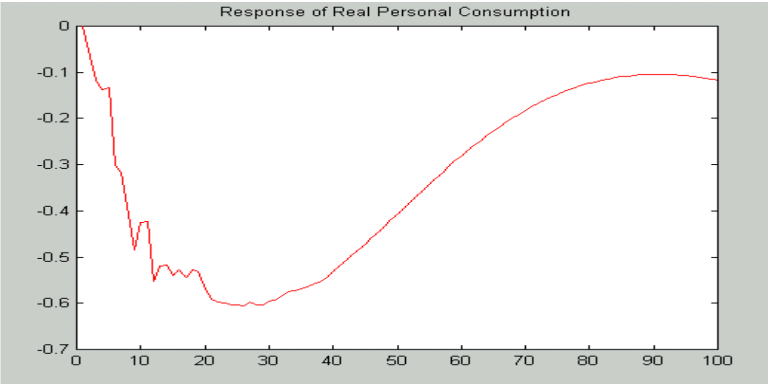

Figure 6

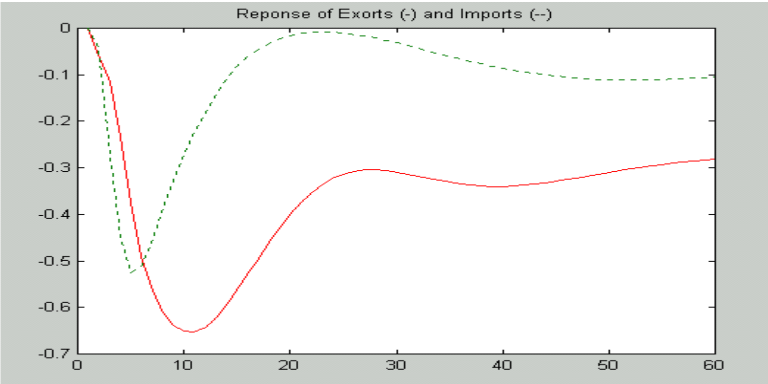

Figure 7

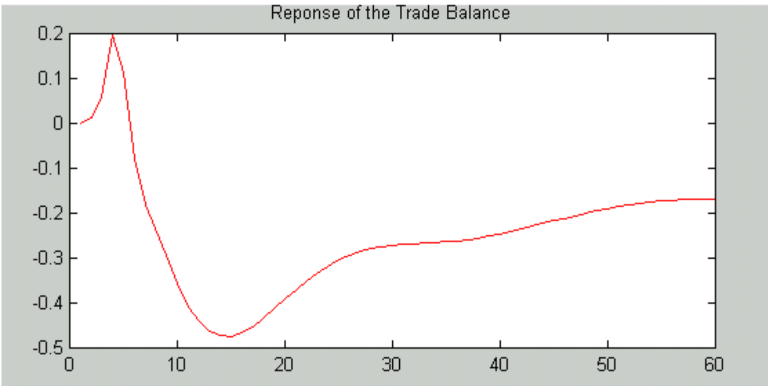

Figure 8

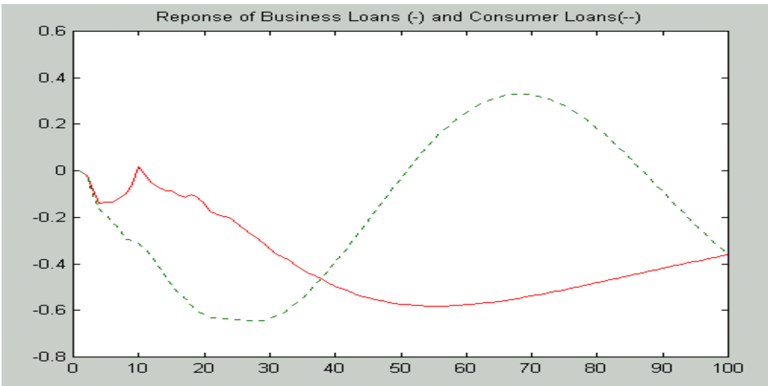

Figure 9