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Francesco Carlucci *

INTERNATIONAL MONETARY SHOCKS AND CURRENCY MOVEMENTS

Abstract

A vector autoregressive (VAR) model linking the economies of the main countries (or monetary zones) in the world – the USA, the Eurozone, Japan and China – is built to analyse the effects on their economies produced by the monetary policy of each one. The economies are characterized by four variables: nominal exchange rate against the US dollar, consumer price, quantity of money in terms of M1, and GDP. The estimation of the VAR model is of the Bayesian type, in order to take into account not only the data but also the opinions of the model builder. Estimation is performed by use of the method of dummy observations as the number of variables is high, twice the maximum normally used in VAR models. A monetary shock in the USA produces the usual effects on economies of the USA themselves, Japan, and the Eurozone, whilst one in the latter increases the output not only in itself but also in the USA. Monetary shocks in Japan and China have poor effects on their own economies.

JEL CLASSIFICATION: C11; C54; E52; F47;
KEYWORDS: Var Model; Bayesian Estimation; Impulse Responses; International Monetary System; Monetary Shock; Exchange Rate

* University of Rome "Sapienza", via del Castro Laurenziano, n. 9, Rome, Italy. Phone: +39-06-49766354. *E-mail address*: francesco.carlucci@uniroma1.it.

1. Introduction

In response to the great crisis of 2008, the world leading monetary institutions (the Federal Bank in the USA, the European Central Bank, the Central Bank of Japan) first reduced their reference interest rates to nearly zero[1], and then increased their balance sheets through the purchase of assets (quantitative easing) in order to promote consumption and domestic investments. But it can be assumed that these institutions, while not openly acknowledging it, have sought to promote economic activity also through the exchange-rate depreciation, factual consequence of monetary easing[2].

In fact, the exchange-rate dynamics is generally regarded as a by-product of monetary policy, as the exchange rate is rarely, in advanced economies, a specific objective of economic policy. In the long run, the benefits from the exchange-rate depreciation should be close to zero, mainly because of higher prices, while in the short run they might exist, with an improvement of the balance of payments at the expense of balances in competing countries.

These argumentations, however, can be questioned. As for the long run, for example, China has long been accused by the US Congress of "manipulating" the exchange rate of its currency, in order to keep it low and thus promote the domestic economic activity[3]. As for the short run, again by example, the lowering of the exchange rate by a country could make the central banks of the competing countries react by implementing measures leading to a depreciation of their currencies, not accepting that the improvement of a competing economy can occur penalizing their own.

This may be possible. But it may be also possible that, again in the short run, the improvement of the balance of payments of a country, due to the

[1] See Eggertsson and Woodford (2003).
[2] See, for instance, Eichenbaum and Evans (1995).
[3] China could reach this result through a high reserve accumulation and a certain degree of capital controls. See, for instance, Rodrik (2008), who analyses the relationship between reserve accumulation and the real exchange rate, or Korineck (2013), who shows how the existence of a negative externality for the aggregate demand, as an insufficient demand, should lead to the implementation of monetary-expansion policies which depreciate the currency.

increase of money supply, results in an increase of its welfare and thus of imports from competing countries[4].

From this framework, complex and uncertain, it is unfeasible to construct a structural model for the world economic system that makes it possible to analyse the effects of monetary and currency policies of the major countries (or monetary zone with a single currency). Too many equations might be specified in one completely different way or another. Thus, in this paper, where such effects are investigated, the main variables that interact in the system (the currency of a country, its exchange rate, output, price), are linearly interconnected with each other without hypothesizing specific relationships. They are inserted into a vector autoregressive (VAR) model, which determines the effects caused on them by specific impulses of some of them considered as instruments. Vector autoregressions are now standard tools for structural analysis in macroeconomics, as they do not impose restrictions on its parameters and allow to capture complex data relations. The size of the VAR model generally ranges from five to nine variables and so makes it difficult to be used in international economics. Thus in this paper a particular shrinkage methodology has been applied to handle fifteen variables.

We build a VAR model that links the economies of the major countries (or monetary zones) in the world - the United States, the Eurozone, Japan and (the People's Republic of) China - to study the effects caused by the monetary policy of each of them. Their economic systems are characterized by the following four variables: nominal exchange rate against the US dollar, consumer price measured with the exception of energy products and food, amount of money in terms of M1[5], and GDP, which is considered to be an indicator of economic growth[6].

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[4] More than thirty years ago Eichengreen and Sachs (1985 and 1986) showed that the devaluations in the thirties had not only not led to the collapse of the international monetary system but also contributed to the world's economic recovery.

[5] M1 was preferred to monetary base to better capture the influence of money on economic activity as, for instance, Leeper, Sims, Zha, Hall and Bernanke (1996) do. Christiano, Eichenbaum and Evans (1999), on the contrary, use M2.

[6] It would be interesting to consider also the inflation expectations, but it was not possible owing to the non-availability of data.

In fact, it would have been more correct to take the reference interest rate[7] instead of the quantity of money as the main instrument of monetary policy, but the latter has replaced the former since 2008 and the use of money in the entire sample period, from 1991 through 2016, has been preferred, assuming, for the years before 2008, an approximate (inverse) relationship between them. In this way, monetary policy is represented by only one variable instead of two.

This policy and the exchange-rate one are supposed to be approximately linked, although they operate in a context of imperfect mobility of international capitals. Thus the VAR model allows you to analyse not only the effects of monetary impulses on economic growth and prices, but also how the exchange rate mediates between these impulses and economic activity, of course regardless of the tools used to implement policies.

The method of estimating the model is not classic but Bayesian[8]. This allowed the subjectivist opinions of the model builder to be taken into account besides the available data. It is a relevant opportunity because the model can be shaped by means of subjective views on international economic policies that are not related to statutory commitments or customary behaviours.

In the methodology, each variables is usually assumed *a priori* not to influence the others, but only itself at lag one. In this paper, on the contrary, some corrections have been made to the method to let the variables *a priori* interact with each other (Section 4).

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[7] As, for instance, Eichenbaum and Evans (1995) do.

[8] The Bayesian Econometrics, which in half a century has been making giant strides and which is used in this paper, was founded by Arnold Zellner, who presented his seminal book "Introduction to Bayesian Econometrics" in a seminar organized in the mid-sixties of the past century by Bruno de Finetti, radical Bayesian. In those years at the Mathematics Department of La Sapienza University, where de Finetti had moved from the Economics Faculty because of health problems, his seminars on Probability, Econometrics, and Mathematical Economics, were frequent. Among others, Koopmans, Lindley, Scarf, Frisch, came to hold the seminars, but there were few participants. There were G. Pala, whom de Finetti had brought as his assistent from the Faculty of Economics, and G. Majone, convinced to leave the USA to teach Mathematical Statistics in Rome (with little luck, because Majone soon returned to the USA). Often came D. Tosato, then young economist, and one or two of de Finetti's undergraduate students.

The following Section sets up the VAR model and lists the variables that compose it. Since the subjective opinions of the model builder must be taken into account, the estimation procedure is Bayesian. But the standard Bayesian estimation method cannot be used because the variables are too many. So, the estimation procedure of Banbura, Giannone and Reichlin (2010) is used as it allows you to handle even several dozens of variables. Section 3 describes such a method while Section 4 expounds the analytical transformation procedure of the initial subjective opinions of the model builder. Sections 5 and 6 report the analyses of the effects of the monetary and exchange-rate policies in the four countries (or monetary zones) performed by two typical analytical techniques: the impulse response functions (Section 5) and the variance decomposition of forecast errors (Section 6). The final Section presents the conclusions.

2. The VAR model and some problems of estimation

Please, So, four variables were considered: the quantity of money in terms of M1[9], the exchange rate national currency/US dollar[10], an index of consumer prices excluding energy products and food[11], the real gross domestic product[12]. For four countries or monetary areas: Japan, the United States, the Eurozone, and (the People's Republic of) China. Because the exchange rate is considered against the dollar, currency of the USA, the exchange rate for this monetary zone has not been used, so that the total number of variables, set in the vector $\mathbf{z}_t$, is 15.

The data set consists of quarterly observations (1991:1-2016:3), which are taken from the OECD data-base of fall 2016. Variables are logarithmized and linked by a VAR model of order 2, as the usual AIC and BIC criteria have suggested the order 1 or 2. Thus, the model is:

$$\mathrm{z_t} = \mathbf{\Phi}_1 \mathrm{z_{t-1}} + \mathbf{\Phi}_2 \mathrm{z_{t-2}} + \mathbf{k} + \mathbf{u}_\mathrm{t} \qquad (1)$$

[9] Index numbers, 100 in 2010. Eurozone with 19 countries.
[10] Eurozone with 19 countries.
[11] Index numbers, 100 in 2005 for Japan, in 2009 for the USA, in 2005 for China. Eurozone with 19 countries.
[12] Market prices.

where $\mathbf{\Phi_1}$ and $\mathbf{\Phi_2}$ are square matrices of order 15 and $\mathbf{k} = [k_1, k_2, \dots, k_{15}]'$ is a vector of 15 constants; is $\tilde{\mathbf{u}}_t$ supposed to be a vector white noise, with dispersion matrix $\sum_u = E(\tilde{\mathbf{u}}_t \cdot \tilde{\mathbf{u}}_t{}')$[13].

The classical estimation of the parameters of the model (1) does not present any difficulty, since the ordinary least squares (OLS) can be used equation by equation, after Cholesky factorizing Σ_u. The Bayesian one, on the contrary, necessary to take account of the subjective opinions of the model builder, is difficult, not to say impossible. Indeed, if you want to include these elements even in the simplest *a priori* distribution (which allows one to take account of the subjective opinions), that by Litterman (1986), also known as Minnesota, when estimating parameters and calculating the impulse response functions, some square matrices of order $15 \cdot (15 \cdot 2 + 1) = 465$ must be inverted. This inversion is computationally not simple, due to the number of variables.

On the contrary, the estimation of parameters of (1) by means of ordinary least squares (OLS) and the calculation of impulse response functions require the inversion of square matrices of order $k = 15 \cdot 2 + 1 = 31$, computationally manageable in a simple way.

But there is a procedure, shown by Banbura, Giannone and Reichlin (2010), which allows estimating the model (1) by OLS and simultaneously utilizing subjective elements in an *a priori* distribution similar to the Minnesota one. It uses additional dummy observations. Let's see it, as it will be used for the objectives of the paper.

3. The Bayesian estimation

The procedure uses the OLS estimation, equation by equation, for the model parameters, assuming that Σ_u is Cholesky factorized[14]. Furthermore, it makes use of the addition of a set of dummy observations, by means of which an *a priori* distribution of the Minnesota type is imposed. The 15 variables are inserted according to the following ordering: M1-USA (US money), M1-EUR (Eurozone money), EXC-EUR (euro/US dollar exchange rate), M1-JAP (Japanese currency), GDP-USA (US GDP), GDP-EUR, M1-CHI (China money), EXC-JAP, PRI-USA (US price), PRI-JAP, EXC-CHI,

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[13] A tilde over its symbol points out that the variable is considered in its stochastic version.

[14] The Cholesky factorization in the VAR analysis was firstly used by Sims (1980).

PRI-EUR, GDP-JAP, GDP-CHI, PRI-CHI. This ordering is defined to set (approximately) earlier the variables that have the greatest impact on the others, and at the end those considered less significant in explaining the others.

The VAR(2) model given by (1) may be written, for t=1, 2,…,n, in the usual regressive form:

$$\mathbf{Z=XB+U}$$

where, $\underset{(n\times 15)}{\mathbf{Z}} = [\boldsymbol{z}_1\ \boldsymbol{z}_2 \ldots \ldots \boldsymbol{z}_n]'$, $\underset{(n\times 15)}{\mathbf{U}} = [\boldsymbol{u}_1\ \boldsymbol{u}_2 \ldots \ldots \boldsymbol{u}_n]'$, $\underset{(\mathrm{n}\times \mathrm{k})}{\mathbf{X}} = [\mathbf{X}_1\ \mathbf{X}_2 \ldots \ldots \mathbf{X}_n]'$ with $\underset{k\times 1}{\mathbf{X}_\mathrm{t}} = [\mathbf{z}_{t-1}{}'\ \boldsymbol{z}_{t-2}{}'\ 1]'$, and:

$$\underset{(k\times 15)}{\mathbf{B}} = \begin{bmatrix} \mathbf{\Phi}_1' \\ \boldsymbol{\Phi}_2' \\ k' \end{bmatrix}$$

is the matrix of parameters to estimate. As the variables are numerous, the procedure by Banbura, Giannone and Reichlin (2010) is followed and 33 dummy observations are added to the original data, i.e. the actual observation matrix Z is enlarged by setting over it the following dummy-observation matrix:

$$\underset{(46\times 15)}{\mathbf{Z}_d} = \begin{bmatrix} diag\left\langle \delta_{1,1}^{(1)}\sigma_1, \ldots, \delta_{15,15}^{(1)}\sigma_{15} \right\rangle / \lambda \\ \underset{15\cdot(2-1)\times 15}{\mathbf{0}} \\ diag\left\langle \sigma_1, \sigma_2, \ldots, \sigma_{15} \right\rangle \\ \underset{1\times 15}{\mathbf{0}} \end{bmatrix}$$

where $\sigma_1, \sigma_2, \ldots, \sigma_{15}$ are the standard deviations of disturbances in univariate autoregressive models constructed for the variables, and $\delta_{1,1}^{(1)}, \delta_{2,2}^{(1)}, \ldots, \delta_{15,15}^{(1)}$ are the values for the autoregression parameters of variables lagged once in the Minnesota *a priori* distribution. Here the assumption is made that the trend of a variable, if exists, is stochastic and the corresponding $\delta^{(1)}$ is 1. If the trend does not exist and the variable is assumed to be stationary, the corresponding $\delta^{(1)}$ is less than 1 in absolute value[15].

The (shrinkage) hyperparameter λ points out how strong the overall subjective opinions of the model builder are: if set equal to ∞, the opinions have no influence and the estimates are equal to the OLS ones; if λ is set equal to 0, the *a posteriori* estimates are equal to the *a priori* ones and the data have no influence on the estimates.

On the other side, again following the procedure by Banbura, Giannone and Reichlin (2010), the matrix $\mathbf{X}$ is extended by means of the following:

$$\underset{46\times31}{\mathbf{X}_d} = \begin{bmatrix} \mathbf{J}_2 \otimes diag\langle \sigma_1,...,\sigma_{15} \rangle / \lambda & \underset{15\cdot2\times1}{\mathbf{0}} \\ \underset{15\times15\cdot2}{\mathbf{0}} & \underset{15\times1}{\mathbf{0}} \\ \underset{1\times15\cdot2}{\mathbf{0}} & kk \end{bmatrix} \qquad (4)$$

where the diagonal[16] matrix $\mathbf{J}_2 = diag\langle 1,2 \rangle$, and kk is a very large number (for instance 10000), indicating the complete uncertainty of the model builder about the values of intercepts.

To interpret the $\mathbf{Z}_d$ and $\mathbf{X}_d$ matrices, it can be noted that their first rows (the first two in $\mathbf{Z}_d$ and the first one in $\mathbf{X}_d$) impose the subjective opinions on the autoregression parameters; the following row imposes the opinions on the dispersion matrix of disturbances; and the last row represents the *a priori* opinion (non- informative) on the intercept. As examples, it can easily be shown that:

[15] In this case both Litterman (1986) and Banbura, Giannone and Reichlin (2010) set $\delta^{(1)} = 0$.

[16] The diagonal elements of the matrix $\mathbf{J}_2$ represent the degree of uncertainty of the model builder, which grows gradually as the lags increase.

$$
\begin{aligned}
&E\left(\tilde{\varphi}_{ii}^{(j)}\right) = \delta_i^{(j)} && \forall i, \forall j \\
&E\left(\tilde{\varphi}_{ik}^{(j)}\right) = 0 && \forall i, \forall k, \forall j, i \neq k \\
&\ldots
\end{aligned}
\tag{5}
$$

Similarly, it can be shown how it is possible to obtain the diagonal elements (the others are taken equal to zero) of the *a priori* dispersion matrix of parameters, of the Minnesota type, when the latter are set in vectorized form.

Adding the dummy observations, the regression model (2) becomes:

$$
\underset{n_* \times 15}{\mathbf{Z}_*} = \underset{n_* \times k}{\mathbf{X}_*} \cdot \underset{k \times 15}{\mathbf{B}} + \underset{n_* \times 15}{\mathbf{U}_*} \tag{6}
$$

where $n_* = n + 46$, $\mathbf{Z}_* = \left[\mathbf{Z}'\,\mathbf{Z}_d'\right]'$, $\mathbf{X}_* = \left[\mathbf{X}'\,\mathbf{X}_d'\right]'$, and $\mathbf{U}_* = \left[\mathbf{U}'\,\mathbf{U}_d'\right]'$, with $\mathbf{U}_d$ matrix of the model disturbances, conform to $\mathbf{X}_d$.

With this addition the mean values of the autoregressive coefficients are shown to be equal to the OLS estimates of (6) and at the same time to coincide with the mean values of the Minnesota *a priori* distribution, as indicated by relations (5). Similarly for the parameters of the dispersion matrix. Note the importance of the result: the VAR model can be easily estimated because the order of the matrix to be inverted is computationally low, despite the high number of variables (even of the order of several dozens of units). At the same time, it is possible to take account of the subjective opinions of the model builder, as in the Minnesota distribution.

4. The a priori subjective opinions

Let's define now the structure of the a priori distribution for the VAR model built in Section 2. First of all, as used in the a priori distributions à la Litterman, the impacts of variables lagged twice are supposed to be zero. Thus: $E(\tilde{\varphi}_{ki}^{(2)}) = \delta_{ik}^{(2)} = 0, \quad \forall i, \forall k$.

As for the lag of one, all variables are supposed to possess a high persistence (which in many cases corresponds to the trend); so we set: $E(\tilde{\varphi}_{ii}^{(1)}) = \delta_{ii}^{(1)} = 1, \quad \forall i$. But, unlike what is usually done in the distributions of Minnesota type, we suppose that a priori also some variables may impact on others, as it happens in reality. In particular, it may be assumed:

- that the quantity of money influences exchange rate and prices in a basic way; therefore:
  - for Japan: $E(\tilde{\varphi}_{5,1}^{(1)}) = \delta_{1,5}^{(1)} = E(\tilde{\varphi}_{8,1}^{(1)}) = \delta_{1,8}^{(1)} = 0.3$
  - for the USA: $E(\tilde{\varphi}_{9,2}^{(1)}) = \delta_{2,9}^{(1)} = 0.3$
  - for the Eurozone: $E(\tilde{\varphi}_{6,3}^{(1)}) = \delta_{3,6}^{(1)} = E(\tilde{\varphi}_{10,3}^{(1)}) = \delta_{3,10}^{(1)} = 0.3$
  - for Cina: $E(\tilde{\varphi}_{7,4}^{(1)}) = \delta_{4,7}^{(1)} = E(\tilde{\varphi}_{11,4}^{(1)}) = \delta_{4,11}^{(1)} = 0.3$
- that the quantity of money influences GDP in a less marked way in all countries or monetary zones:
  - $E(\tilde{\varphi}_{12,1}^{(1)}) = \delta_{1,12}^{(1)} = E(\tilde{\varphi}_{13,2}^{(1)}) = \delta_{2,13}^{(1)} = = E(\tilde{\varphi}_{14,3}^{(1)}) = \delta_{3,14}^{(1)} = E(\tilde{\varphi}_{15,4}^{(1)}) = \delta_{4,15}^{(1)} = 0.1$
- that the exchange rate influences prices and GDP in all Countries or monetary zones:
  - $E(\tilde{\varphi}_{8,5}^{(1)}) = \delta_{5,8}^{(1)} = E(\tilde{\varphi}_{12,5}^{(1)}) = \delta_{5,12}^{(1)} = E(\tilde{\varphi}_{6,10}^{(1)}) = = \delta_{6,10}^{(1)} = E(\tilde{\varphi}_{14,6}^{(1)}) = \delta_{6,14}^{(1)} = 0.2$
  - $E(\tilde{\varphi}_{11,7}^{(1)}) = \delta_{7,11}^{(1)} = E(\tilde{\varphi}_{15,7}^{(1)}) = \delta_{7,15}^{(1)} = 0.2$
- that the remaining impacts are zero.

A low value17 is given for λ, 0.08, showing the strong degree of belief by which the opinions of the model builder are expressed. By constructing a univariate autoregressive model of fourth order for each variable, the following values for the standard deviations of disturbances are obtained:

$$\begin{aligned}
&\sigma_1 = 0.013, \sigma_2 = 0.045, \sigma_3 = 0.004, \sigma_4 = 0.010, \sigma_5 = 0.012, \\
&\sigma_6 = 0.005, \sigma_7 = 0.005, \sigma_8 = 0.011, \sigma_9 = 0.039, \sigma_{10} = 0.023, \\
&\sigma_{11} = 0.004, \sigma_{12} = 0.023, \sigma_{13} = 0.041, \sigma_{14} = 0.007, \sigma_{15} = 0.005
\end{aligned}$$

[17] Usually set to 0.10 by the users of Minnesota distribution.

5. Monetary shocks in the USA, the Eurozone, Japan and China

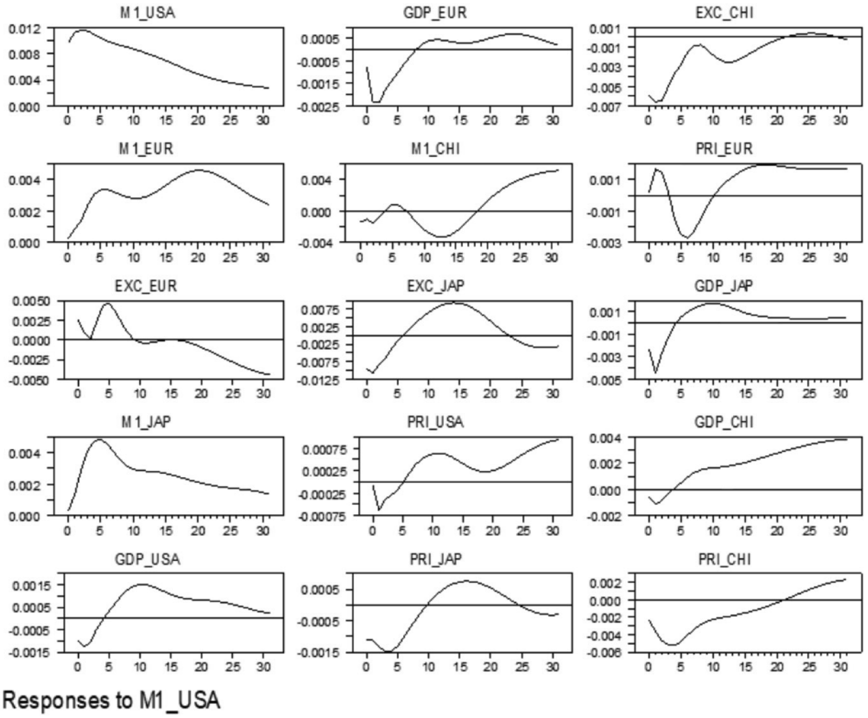
Although the VAR models are the reduced form of simultaneous structural models, the statistical significance of their parameters or the correlation between these is not of great interest. The usefulness of the VAR models concerns instead the overall effects on specific variables produced by shocks imposed on (the disturbances of) some of them. These effects are shown for a pretty long period of time and constitute the so-called impulse (the shock imposed on a variable) response (the effects on another) function (IRF).

This Section examines some IRFs that are considered interesting for the objectives of the paper. Figures 1, 2, 3 and 4 show the responses of the 15 variables in the system, over 32 quarters, to impulses applied to the quantity of money (M1) in the USA, the Eurozone, Japan and China, respectively. Shocks consist of one standard deviation (of disturbances) and in the figures the effects on variables are measured in terms of their own standard deviations.

5.1. Effects of a monetary shock in the USA

Figure 1 shows the IRF induced by a shock to US money. The GDP of this monetary zone (GDP-USA) initially falls and then grows steadily to its maximum (after 10 quarters). Then it returns to neutrality. The same trend is found in other analyses, one of which, among the main ones, is by Leeper, Sims, Zha, Hall and Bernanke (1996). As usual, there is the price-puzzle, consisting of price (PRI-USA) that falls simultaneously with the shock to money, and then grows in both the short and long term.

Figure 1. Impulse responses to a shock to US money



The sudden growth of US money is immediately reflected in a fall of the yen/dollar exchange rate (EXC-JAP). Japan's GDP declines significantly with the delay of one quarter but monetary authorities appear to intervene by increasing (albeit slowly) money and improving both the exchange rate and output. Moreover, Eurozone’s monetary authorities appear to react much better than in Japan, as the euro/dollar exchange rate (EXC-EUR) is not particularly affected. Eurozone’s output (GDP-EUR), on the other hand, is affected, as in Japan (GDP-JAP), with the minimum after two quarters. Eurozone’s (PRI-EUR) and Japan’s (PRI-JAP) prices possess similar trends.

The latter grows as the result of the increase in money, after having shown the price-puzzle: Eurozone's price falls to its minimum after six quarters since the monetary shock, while Japan's price reaches the minimum after three. Similarly, China's price (PRI-CHI) falls in the short term (the minimum is after three months), while its GDP increases slowly but steadily, in both the medium and long term.

5.2. *Effects of a monetary shock in the Eurozone*

Figure 2 shows the IRFs induced by a shock to Eurozone's money. It produces the expected effects on its own economy: after the initial increase, its M1 steadily declines until the simulation end; its GDP grows steadily up to its maximum over five quarters, and then returns to neutrality, which reaches after ten quarters. Likewise for price, which grows up to the maximum over seven quarters and returns to the normal path more slowly. So, the behaviour of Eurozone's economy after a shock to its money seems to be quite similar to that of US economy as the result of a monetary shock.

The effects on the other countries, which are very weak indeed, do not look like the expected ones. The euro in the medium term appreciates lightly against the dollar (EXC-EUR) and consequently in the period 4-8 quarters both output and price grow a little in the USA. In Japan, GDP only has a light positive initial jump and its price a negative one.

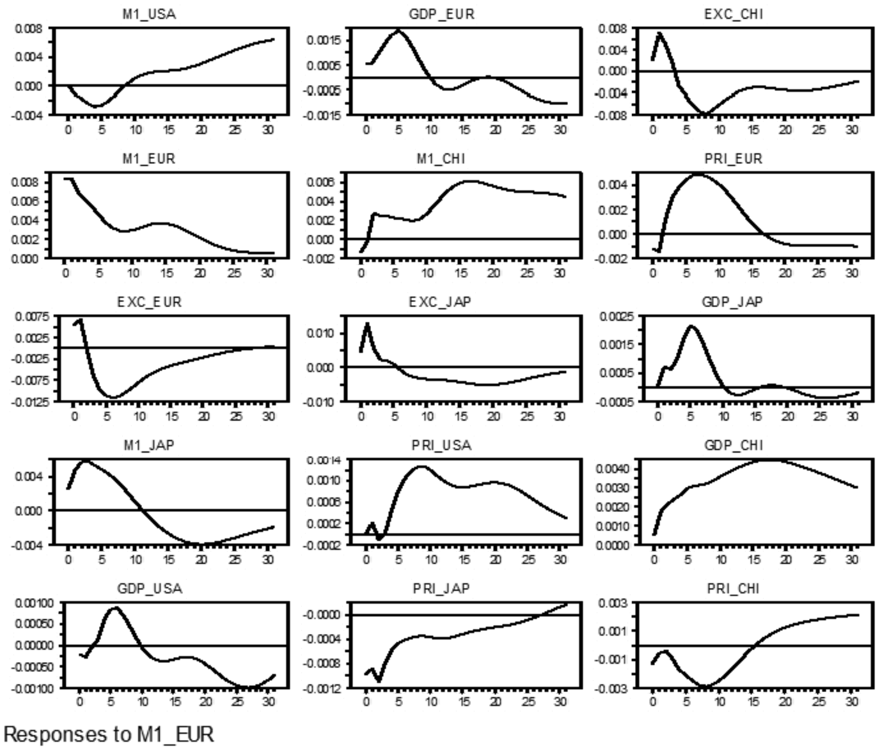
In all probability, there is a growth in consumption in the Eurozone and hence an increase in imports from the USA and Japan. Also China's GDP does not contract, but expands robustly and consistently in both the short and long term.

5.3. *Effects of a monetary shock in Japan*

A monetary shock in Japan (Figure 3) produces poor results on its own economy: its GDP initially declines and then grows, but lightly (3-7 quarters). Its price has a positive outbreak lasting one quarter only, and afterwards it returns to the normal path. Also the effects on US, Eurozone's and China's outputs are not substantial: initially zero, they become positive only in the medium term and over a short time. They reach the maximum after 10 quarters in the USA and after 13 in the Eurozone. China's GDP increases steadily, but slowly, up to the maximum after twenty-five quarters.

Prices in the USA and Eurozone behave accordingly: they start rising almost immediately in the Eurozone and after five quarters in the USA. The former reaches the maximum after four quarters while the latter reaches it slowly, after fourteen.

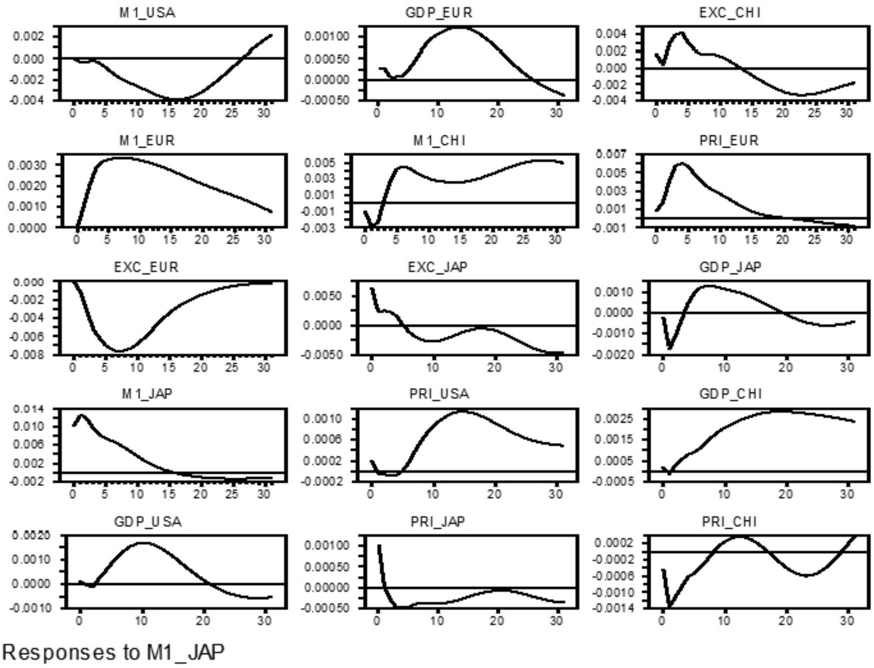
Figure 2. Impulse responses to a shock to money in the Eurozone



It is interesting to note that the monetary shock in Japan immediately lowers its exchange rate (EXC-JAP), which, however, returns to its normal path (and stays there) after four quarters. The effects on Eurozone's exchange rate are much slower: even if the euro begins to appreciate after one quarter, it reaches the maximum appreciation after seven. It returns to its normal path only in the long run, after thirty quarters.

To sum up, a standard monetary shock in Japan produces poor results. Probably the country would require very strong shocks to really improve its economic activity.

Figure 3. Impulse responses to a shock to money in Japan

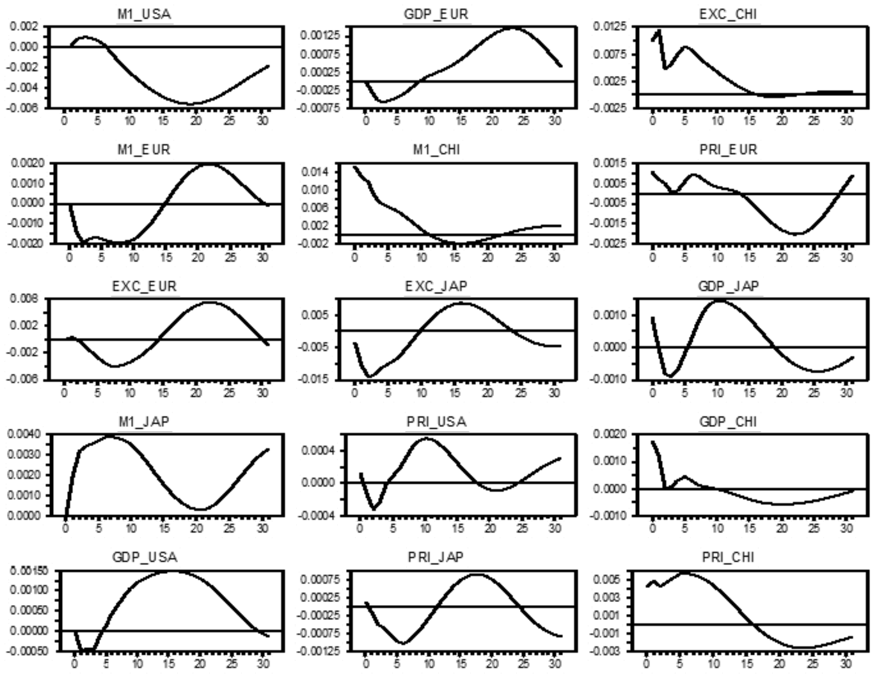


5.4. Effects of a monetary shock in China

The effects of a monetary shock in China (Figure 4) are relatively non-orthodox. First, it has a very marginal impact on its own GDP (GDP-CHI): it increases only in the first quarter after the shock, and then returns to its normal path. It is more effective on domestic price (PRI-CHI), which grows immediately and remains higher than normal over 15 quarters.

After a slight decline, evident in Japan but very low in the USA and the Eurozone, GDPs of the other three countries (or monetary zones) increase very lightly: quickly in Japan, for which output reaches the maximum after 11 quarters; slowly in the USA, with the maximum after 15 quarters; even more slowly in the Eurozone with the maximum after 23 quarters. Also price moves, even much lightly: it decreases in the short term in the USA (minimum after two quarters) and in Japan (minimum after six). Then it reaches the maximum, which is in the USA in the tenth quarter, and in Japan in the eighteenth. On the contrary, in the Eurozone price is not undergoing major alterations in the short-medium term.

Figure 4. Impulse responses to a shock to money in China



Responses to M1_CHI

To sum up, the effects of a monetary shock in China seem to be very poor, for the country itself and other three countries.

6. The decomposition of the forecast-error variance

A second type of analysis that can be done through the VAR models concerns the decomposition, for each variable, of the forecast-error variance. This analysis makes it possible to determine the importance of each variable in explaining the variability of one of them. And since the forecast involves a long period of time, such an analysis is dynamic, in the sense that it is possible to see how this importance evolves over time, diminishing or widening. Figures 5 and 6 show the decompositions of the forecast-error variance made over 32 quarters ahead for some relevant variables: US, Eurozone's and Japan's outputs, as well as US and Eurozone's prices. They indicate how much of their variance, as a percentage, is due to US, Eurozone's and Japan's money and GDP.

To interpret these results well, it should be noted that in Figure 5 the percentages of explained variance are all between 0% and 10%, while in Figure 6 in only four cases they vary between 0% and 100%, and in two cases between 0% and 30%.

Let's first look at Figure 5. US output is highly influenced by US money, as expected, but also by Japan's money in the medium term, and not by that of the Eurozone.

This fact seems to confirm the implications of the impulse responses: US output responds positively to a Japanese monetary shock in the medium-long term (10-20 quarters) but poorly to a monetary shock in the Eurozone. The money of the latter, as expected, partly explains the variability (in forecast) of its own output, while does not affect the GDPs of the USA and Japan, if not lightly in the medium-long term.

Lags are those theoretically expected: US money has the greatest impact on US GDP after 12 quarters, and afterwards the impact remains constant, while Japanese money has a maximum that is more delayed.

Taking account of dimensions, Japanese money seems to affect more significantly the US output than the Japanese one, which appears, probably by virtue of monetary channels (through bonds, for instance), much less responsive. An impact of Japanese money that is similar, but dimensionally more limited, appears on Eurozone's GDP, as shown by the comparison of the first two panels high on the right in Figure 5.

US price is heavily influenced by monetary variations in the USA themselves, while it is poorly affected by what is occurring outside, in the Eurozone and Japan. A similar fact happens to Eurozone's price, which however seems not to be affected by changes of its own money.

Furthermore, it does not seem that the Japanese money variations, even if impacting on outputs of the USA and Eurozone, have any effect on their prices.

Figure 5. Percentages of the forecast-error variance due to the US, Eurozone's and Japan's money for five variables

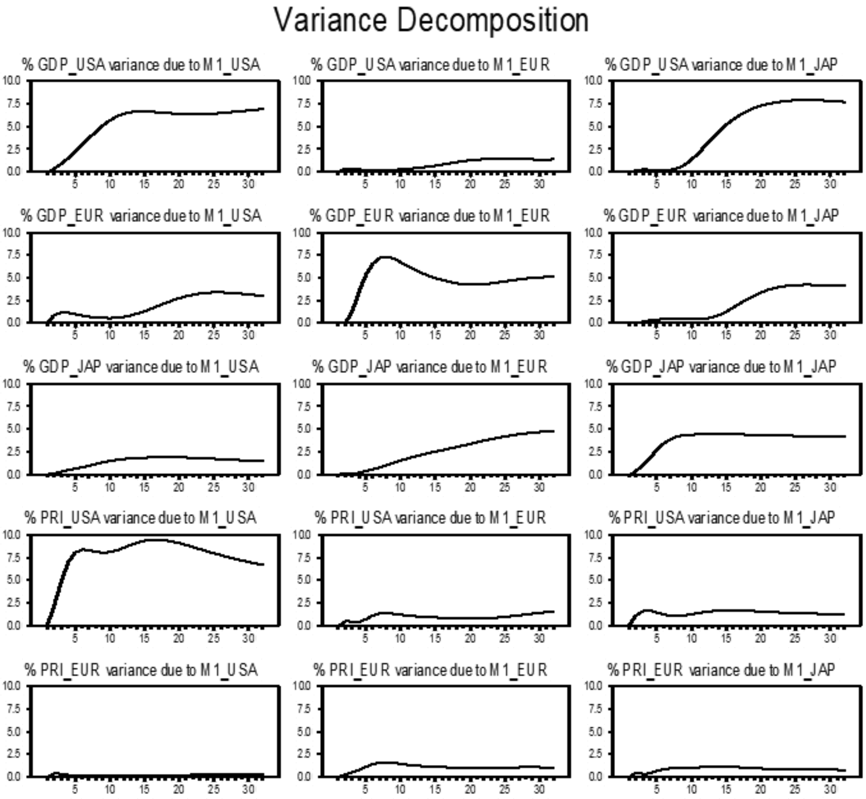
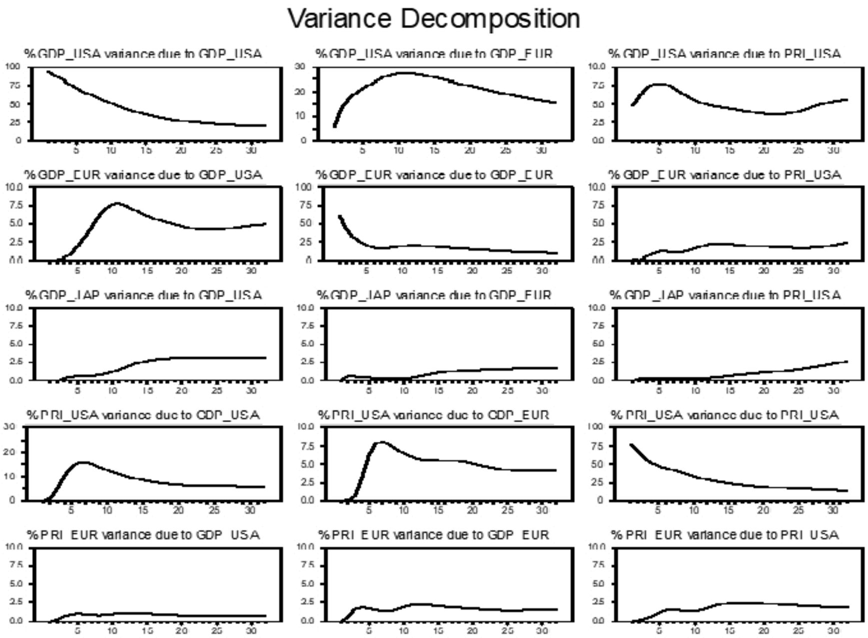


Figure 6 analyses the variance percentages that are attributable no longer to money, but to US and Eurozone's GDPs as well as US price. This is related to US GDP with a light impact, as expected, whilst it appears to be largely irrelevant to the GDPs of the Eurozone and Japan. Instead, US and Eurozone's GDPs lightly affect each other, with a maximum of about ten quarters in both directions. Strangely, Eurozone's price is not affected by US GDP, while US price is lightly affected by Eurozone's output in the short term (5-7 quarters). This latter influence goes on in the medium-long term.

To sum up, the figure seems to show that prices interact very weakly between the USA, the Eurozone and Japan. A similar weakness is perceived in the links of their outputs, with the possible exception of a light impact between the output of the USA and the Eurozone.

Figure 6. Percentages of the forecast-error variance due to the US and Eurozone's GDP, as well as to US price, for five variables



China is not considered in the decomposition of the forecast-error variance as it has proven not to be influenced economically by the other countries, nor influencing them.

7. Concluding remarks

The effects of the international monetary shocks can be easily analysed by means of the VAR models, which do not require the specification of particular relationships between variables. In the paper, a VAR model containing four variables for four countries is built. The variables are: money, national-currency/US-dollar exchange rate, consumer price index, and GDP; the countries (or monetary zones): the USA, the Eurozone, Japan and China. Using the Cholesky factorization, the model, despite the high number of variables, can be estimated with the ordinary least squares.

But estimation has to be of the Bayesian type in order to be carried out by exploiting the subjective opinions of the model builder. This can be done by adding some dummy observations to the real ones. The procedure for this addition is described in Section 4 and its implementation to the case of this paper in Section 5. In the previous literature variables are supposed a priori not to affect the others, but only themselves at lag one. In this paper, on the contrary, some corrections have been made to the methodology to allow each variable to interact a priori with the others.

The analysis of the effects of monetary shocks and the decomposition of the forecast-error variance has produced sometimes expected, sometime unexpected results. A monetary shock in the USA has expected effects: an improvement in the US GDP and a worsening in the Eurozone's and Japan's outputs; increase of price in the USA and decrease in the other countries. The only exception seems to be China's GDP, which grows slowly but steadily after the shock. On the contrary, a monetary shock in the Eurozone, while increasing the output of its member countries, does not diminish that of the USA, nor those of Japan and China. Even US price is somehow affected by a light increase. Instead, Japan's and China's prices show a first negative impact, which is absorbed only in the medium (for China) or long term (for Japan).

The effects of a monetary shock in Japan are poor for its economy. In the USA and Eurozone they are the opposite of those expected: outputs improve and accordingly prices increase. China's GDP also increases, slowly but steadily. The monetary shock in Japan immediately lowers its exchange rate, which returns after a year to its normal path. In China, a monetary shock that occurs in the country does not produce significant effects on its GDP. It is more effective on its domestic price, which grows immediately and remains higher than normal over 15 quarters. The effects on economies of the other countries are very light.

US output is heavily influenced, in dynamic-regression terms, by US money, as expected; very lightly by GDP of Japan in the medium term; and not by that of the Eurozone. The money of the latter, as expected, partly explains the variability of output of the Eurozone itself, while not affecting the GDPs of the USA and Japan, if not lightly in the medium-long term.

In forecast terms, US and Eurozone's GDPs seem only lightly influence each other. US price is heavily affected by monetary variations in the USA themselves, while it is not affected by what is happening in the Eurozone and Japan. Strangely enough, Eurozone's price seems not to be influenced by changes of its own money, nor by US GDP, while US price is somewhat affected in the short term by Eurozone's output. This latter influence continues in the medium-long term.

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