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Short-term modeling with various vector autoregression and state space models : applications to Trinidad and Tobago

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Until a still recent day, economic modeling in the Caribbean revolved around traditional econometric models. Initiated with the works of Harris (1970), Carter (1970) and Kennedy (1966), modeling practice was the object of numerous works carried out in university laboratories, as well as in central bank research centers. In terms of quantity, the assessment is relatively positive since one can now make a census of about thirty models for the English Speaking Caribbean Countries (see Craigwell et al. (1995) for a survey).
However, when it comes to the quality and finality of these models, the assessment is greatly mitigated. These models have been the subject of various and sometimes rather sharp criticisms on either their conception, their relevancy for economic reflexion, or their capacity to describe mechanisms which are specific to insular Caribbean countries. In the same way, when referring to the evolution of modeling in developped countries, one won't fail to underline that the process of model elaboration has not reached yet its maturity stage in the Caribbean. The majority of existing models has mainly been used in an educational context which has been limited to equations estimation and to the inspection of graphs of comparison of observed and adjusted data. Consequently, very few of them have served for the preparation of government policies and for the simulation of economic measures.

Yet, today, as the Caribbean decision-makers are becoming aware of the well-groundness of models as tools for helping to make decisions, this situation will soon become old-fashioned. So, with the renewal of econometric methodology induced by the concepts of cointegration and errors correction mechanisms, one should expect caribbean economists and econometricians to invest themselves much more in model construction.

Following the example of Watson and Teelucksingh (1995), these works could begin with the re-writing of existing models. However, on account of the lack of statistical organizations providing data, and above all, the absence of quarterly economic accounts, a part of these works will only concern annual models.

Yet, if the decision-maker needs annual models to analyse and define the prospects of economic evolution in the medium term, he also needs tools to guide his action in the short term. The necessity of short term prospective studies and the lack of adequate models constitute a true dilemma for the Caribbean countries.

To bring solutions, most of the works presented in the recent literature is dedicated to the application of time series methodologies. Today, il est bien établi que time series methods offer good alternatives when structural econometric model are absent or trop fastidieux et couteux to construct. Indeed, among these times series methods, plusieurs permettent to analyse economic

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We would especially like to thank Professor Masanao Aoki for sending us his last works on state space modeling, and are very grateful to Professor Arthur Havenner for sending us his speakeasy program for numerical applications.

structure of a country and to study the relationships between key variables representative of this economy. In the same way, many works showed that time series techniques gave comparable, or even superior results to the traditional macroeconometric models in the context of forecasting (McNees (1986), Makridakis (1986), Wallis (1989), Aoki (1990)).

Until then, the empirical studies were mainly devoted to confront VAR models to others. Even though Aoki proved since 1987 that state-space approach is more general than VAR approach and provides models with better properties, studies aiming at comparing the two approaches are still insufficient and must be carried out on various aspects : data nature, model size, use, etc.

Our article is in keeping with this prospect since it proposes a comparison between these methods in order to appreciate their qualities both for forecasting and economic analysis. The structure of our paper is the following. We begin with presenting briefly the various VAR and state space models underlying the main results of literature. Then we point out their applications in two directions. Firstly, we conduct a competition based on a five variable system gathering time series from Trinidad and Tobago. Secondly, we tackle their use to study dynamic interactions between the variables by means of impulse response function.

1. The models and procedures

1.1 The vector autoregression approach

The use of VAR models has been recommended by Sims (1980) as an efficient alternative to verify causal relationships in economic variables and to forecast their evolution. On the theoretical level, this approach has its foundation in the work of Wold (1938), Box and Jenkins (1980) and Tiao and Box (1981). Given Y_t the vector of variables, the classical VAR model explains each variable by its own p past values and the p past values of all other variables by the relation

$$Y_t = d_0 + \sum_{k=1}^{p} \Phi_k Y_{t-k} + \varepsilon_t \qquad (1)$$

where the Φ_k are $n \times n$ matrices, d_0 the deterministic component which can include a constant and seasonal dummies and ε_t is a zero-mean vector of white noise processes with positive definite contemporaneous covariance matrix Σ and zero covariance matrices at all other lags.

To calculate the $n \times (np+1)$ estimators of the parameters in (1), it is well known that application of least squares method equation by equation is justified. Moreover, it is established that the coefficient estimates coincide with the maximum likelihood estimates and are consistent and asymptotically efficient (Lütkepohl (1993)).

For pratical use, estimations of VAR model involve that long time series are available. For selection of the optimal lag structure, one usually choses the p values that minimize different information criteria (Akaike, Schwarz or Hannan and Quinn).

In order to answer to the criticisms against Sims standard formulation, in particular problems caused by over-parametrisation, Litterman suggested the use of the Bayesian procedure. For VAR model, the application of the Bayesian pinciple implies that an a priori probability has to be chosen. Yet, since most of the macroeconomic variables are from stochastic tendencies, the specification of their distribution turns out to be necessary. Usually, the hypothesis of normality for the coefficients is adopted since, in most cases, the underlying economic theory has little influence on the distribution of errors.

More precisely, Litterman (1980) introduces some a-priori knowledge in the formulation of his model by means of a distribution of probabilities, considering the following point of vue : being strictly in a situation of normality, with the exception of the coefficient corresponding to the lag of one period, he states that the coefficients are indépendant two by two and subject to a distribution of zero mathematical expectation and of a rather low standard deviation.

This approach aims to consider that the coefficients related to long-term lags can be non-zero, although it is worth noticing that they are closer to zero than those related to short-term lags. What is original in this approach is the fact that it is as if it were a necessary arbitration between the over-parametrisation on the one hand, which integrates too many non-significant coefficients with high standard deviation, and the under-parametrisation, on the other hand, which cannot be satisfactory because some variables and/or some lags are completely missed out when forcing some coefficients to take the zero value.

The Bayesian procedure suggests that the standard deviations of the coefficients decrease as fast as lags increase. It is thus a particularly useful means of improving forecasts as it enables long-term lags to be estimated. It is also worth noting that this procedure preserves the atheoretical character of the VAR models and shows the possibility of significant uncertainties in the actual structure of the economy as it is not based on a particular economic theory. This way of grasping the problem however leads to a major difficulty. In fact, logically, it is necessary to acknowledge that, unlike the method of simple regression, where a good knowledge of the category of lags of the coefficients is available, especially thanks to the conditions of stability, the a priori ideas about lags related to other variables are sufficiently hazy. Yet, because of the very large size of the variances covariances matrix, it is unfortunately impossible to carry out this principle at this level since it is hardly likely that a thorough rule can be specified in good conditions. In practice, it is usually done as follows : a set of coefficients of identical rule and arguments called hyperparameters is chosen. These are considered to be fixed in the estimation of the model. Morever, it holds values for the coefficients which are all the more close to zero as they correspond to less and less recent periods which happened before the moment when the forecast was carried out.

If estimation of models incorporating relations of cointegration were used in the late 1990's essentially to apprehend questions about causal relationships existing between economic variables, today more and more varied applications are proposed in the context of forecasting (see Engle and Yoo (1987), Clements and Hendry (1995), Lin and Tsay (1996)). Conciliating the ECM approach with the VAR one, the estimation step by the maximum of likelihood of Johansen (1988) constitutes the central phase of the method. The ECM model is formulated in the following way.

$$\Delta Y_t = d_0 + \Pi_0 Y_{t-1} + \Pi_1 \Delta Y_{t-1} + \ldots + \Pi_{p-1} \Delta Y_{t-p+1} + \eta_t \qquad (2)$$

with

$$\Delta Y_t = Y_t - Y_{t-1}\,,\ \Pi_i = -\sum_{j=i+1}^{p} \Phi_j\,,\quad i=1,\ldots,p\text{-}1\,,\ \ \Pi_0 = -\Phi(1)$$

It leads to the function forecasting given by (3) and to the procedure below for compute the forecasts.

$$\Delta Y_{t+h/t} = d_0 + \Pi_0 Y_{t+h-1/t} + \sum_{i=1}^{p-1} \Pi_i \Delta Y_{t+h-i/t} \qquad (3)$$

Forecasting procedure with the VECM method

Step 1 : Use the Johansen FIML estimation procedure for determining the number of cointegrating vectors and obtaining estimates of the long-run relationships $\hat{\beta} Y_t$ between the variables.

Step 2 : Use the long-run relations $\hat{\beta} Y_t$ for defining the error-correction terms to be included in the VAR model and estimate the resulting VECM model.

Step3 : Compute the forecasts with (3)

1.2 The state space approach

Based on the formalism of mathematical system theory and models developed by systems engineers for optimal control of physical process, economists had, during these past three decades, elaborated different system-theoretic concepts and associated tools in order to analyse the dynamic of economic variables.

These tools have firstly concerned the application of dynamic optimization techniques and of calculation of variations in search of optimal trajectories in the context of economic policy (see Chow (1975), Preston (1974), Aoki(1976), Pagan and Preston(1982), Kendrick(1976), Murata(1982)). The essential aspect was that the techniques of estimation, resolution and simulation of the economic models considered relied on Bellman (1954), Pontriaguine et al. (1974) and Kalman (1960,a,b) algorithms. Until the early 1980's, the supporters of this modeling approach had thus developed an abundant literature. The main result was that they proposed a methodological framework generalizing Theil and Tinbergen theory relative to the analysis of dynamic properties of economic models and the evaluation of optimal economic policies.

Nevertheless, during the late 1980's, the interest for this approach decreased, following discussions generated by Lucas (1976) and Kydland and Prescott (1977) famous criticisms.

In the quest to renew the state space modeling, answers to these criticisms have recently led to methods taking into account expectations economic agents (see Zeeuh and Van Der Ploeg (1991) for a presentation). The economic policy analysis is apprehended in the context of differential game for which the conceptual frame of state models remains applicable.
This renew interest in state space approach is also due to the new methodology proposed by Aoki (1983, 1987a). Based on stochastic realization theory, this methodology aims at building a state model directly from the observed data. These models are obtained with strong algebraic techniques and a procedure which solves simultaneously problems of model selection and parameter estimation. The procedure has been well described in the Aoki papers, as a consequence we just outline below his main steps.

Let $\{y_t; t = 1,\ldots,N\}$ be a set of centered and stationary observations of a y vector which regroups q variables representating the evolution of an economic phenomenon observed at the instants $t=1,\ldots, N$ and let the innovation form[3] be :

$$\begin{cases} z_{t+1} = Az_t + Ge_t \\ y_t = Cz_t + e_t \end{cases} \tag{4}$$

where the innovations e_t are both serially independant with covariances Δ_e and independent of state variables z_t $(Cov(z_t, e_t) = 0; \forall t, l)$. The usual procedure to determine the parameters (A, G, C) which "realize" the system (10) is composed of the following stages.

(i) construction of the Hankel matrix

One computes $\hat{H}$ a $qf \times qr$ matrix approximation of the Hankel hypermatrix associated to the autocovariance function $\{\Delta_k = Cov(y_t y_{t+k})\}$, r and f being respectively the number of block-columns and the number of block-lines by columns.

(ii) Choice of the model order

The chosen value for the number of components of the state vector is determined firstly by deciding the values to give to the parameters r and f. Great values entail a minimal loss of information in the approximation of Hankel matrix by $\hat{H}$ but, in return, generate bigger errors. Then, the number of states n that can synthetize the information contained in $\hat{H}$ is given by the rank of this matrix defined as the number of nonzero singular values of $\hat{H}$ (Kronecker theorem).

(iii) Calculation of the matrixes $\hat{A}$, $\hat{G}$ and $\hat{C}$

The structure of the matrixes Δ_k defined in terms of the parameters of the model (10) and of the covariances Π et Δ_k enables the matrix H to have the remarkable property of being written as the product of the observability matrix ($\hat{\mathrm{O}}$) by a matrix whose form is similar to that of the commandability matrix ($\hat{\mathrm{C}}$) of system (10)

So, the estimators $\hat{A}$, $\hat{G}$ and $\hat{C}$ are calculate by performing two factorizations of the matrix $\hat{H}$.

The first is its singular values decomposition : $\hat{H} = \hat{U}\hat{\Sigma}\hat{V}$. For the second $\hat{H} = \hat{\mathrm{O}}\hat{\mathrm{C}}$, one chooses the solution which rely on the balanced representation of Moore (1981).

With these decompositions, the estimators of the parameters are obtained in two stages.

Firstly, we show that $\hat{A}$, $\hat{\Omega}$ and $\hat{C}$ are given by :

$$\begin{aligned} \hat{A} &= \Sigma^{-\frac{1}{2}} U' \bar{H} V \Sigma^{-\frac{1}{2}} \\ \hat{\Omega} &= \Sigma^{-\frac{1}{2}} U' H^{\Omega} \\ \hat{C} &= H^{C} V \Sigma^{-\frac{1}{2}} \end{aligned} \tag{5}$$

The matrices H^C and H^{Ω} being defined as follows

$$H^C = \left[\hat{\Delta}_1 \;\; \hat{\Delta}_2 \;\; \cdots \;\; \hat{\Delta}_r\right]; \; H^{\Omega} = \left[\hat{\Delta}'_1 \;\; \hat{\Delta}'_2 \;\; \cdots \;\; \hat{\Delta}'_f\right].$$

[3] The innovation form stands out by the presence of the same innovations in the state equation and the observation equation. The choice of this model does not lose generality because the passage to the classical model is done by a spectral factorization of the matrixes (A, G, C).

and $\tilde{H}$ is constructed by shift up $\hat{H}$ by one submatrix row.

Secondly, we calculate $\hat{G}$ by the formula $\hat{G} = (\Omega - A\Pi C')(\Delta_0 - C\Pi C')^{-1}$.
The matrix Π is solution of the following Riccati equation which ensures the stationarity of the process $\{x_t\}$:

$$\Pi = A\Pi A' + (\Omega - A\Pi C')(\Delta_0 - C\Pi C')^{-1}(\Omega - A\Pi C')' \qquad (6)$$

with $\Pi = E\{x_t, x_t'\}$.
Its resolution may be apprehended by an iterative algorithm which initialyzes the matrix Π to the zero matrix and which achieves its updating directly from relation (6). Another process is based on a non-iterative algorithm similar to the one introduced by Laub (1983).

Since Aoki's (1983) founding work, empirical studies and other econometricians' contributions have considerably enriched the field of of system theoretic methods in econometric literature.

As for investigations, Vinod and Basu (1995) used american data and estimated a model for consumption, income and interest rates. They used it to get a different point of view on the empirical tests of the business cycle theory. In a very recent work, Aoki and Havenner (1997) have gathered articles which present a wide diversity of economic applications. For example, Fiorito (1997) investigated impact of labor and good market comovements on aggregate fluctuations in the US economy after the first oil shock. Using a vector of the real GDP, labor force, employment, real wages and money stock, they apply standard Aoki algorithm to estimated a state space model and associated residuals. From these residuals, they computed impulse response functions, examined structural shocks and give an interpretation of business cycle comovements in the US ranging from 1976 to 1990. An another interesting example is the one of Östermark (1997) which studied the impact of Japanese stock prices on the Finnish derivatives market. By means of a state models they obtained an appoximation of the common trend and cyclic components of the variables considered and analyse their content by spectral analysis.

Concerning methodological contributions, one can cite numerous references. Among them, Otter and Van Dal (1987) formulated a variant of the original Aoki method which uses a Hankel matrix defined from the covariances between the innovations and the studied data. In the same year, Havenner and Criddle (1987) suggested a procedure which relies on a Hankel matrix built from centered and reduced data. Mittnik (1989) also studied several identification schemes from a state representation in which the state vector is brought up to date from the output observed at instant t instead of the innovation of this same instant. Dorfman and Havenner (1992) developed a Bayesian procedure which contributes full posterior distributions for parameters and simplifies the problem of model specification.

2. Data and preliminaries treatments

Since the end of the first oil crisis, the analysis of infra-yearly evolutions of the economical variables has become necessary for private and public policy-makers who must define and adjust their actions at best. In view of this, it is on the quartely data basis that studies are usually achieved to identify the sources of economical fluctuations and to study the properties of the GDP.

To carry out the two kinds of exercices that are considered in this article, we have chosen a five variable system which is usually used for the analysis of business cycles. These variables are the GDP, the level of unemployment and the index of retail prices and are representative of the real sector. The other two are the Treasury Bill Rate and the total bank deposits that represent the monetary sector. All the time series gather data for the 1971:Q1-1996:Q4 period. Their exact definition and way of construction are well described in Watson (1997).

Before elaborating forecasts from the multivariate models considered here, it is necessary to characterize the intrinsic dynamic of each variable by unit roots tests. Of course, it is the custom to take Dickey and Fuller (1981) procedure in order to test the presence unit roots at the zero frequency. Although this procedure has been used systematically in most empirical works, some authors have recently questionned them and underlined the necessity of using other tests. Dickey and Fuller tests impose a deterministic linear trend as alternative hypothesis, which can lead to a systematic biais towards accepting the null of a unit root in the presence of a structural break. As alternatives many authors proposed tests procedures which account for the evolution of the trend of the series concerned. Perron (1989) has proposed a methodology which allows to test the presence of a deterministic trend and a structural break. By adopting a non parametric approach like Phillips and Perron, Ouliaris, Park et Phillips (1989) have proposed a more general test which describe the deterministic component of the time series by polynomial trend. An another example is the Zivot and Andrews (1992) test which introduces a non linearity effect in the deterministic trend.

If we examine the plots of the data, we can accept the evidence of structural break occuring in 1982. So it seems necessary to apply adequate unit root tests. So, we performed the perron procedure with a dummy equal to zero for all values of $t \leq 1982{:}4$ and equal 1 to beginning in 1983:1. Results for the variables in level as well as for the first differences are reported in table 1. The critical value for the t-statistics is -3.96. For all series, we conclude to the imposibility to reject the null hypothesis of a unit root in presence of a structural break.

Table 1. Perron unit roots tests

	GDP	Unemp	Prices	Deposits	TBR
In level	-1.870	-2.576	-3.148	-2.115	-3.402
In differences	-6.131	-5.811	-5.874	-10.36	-7.496

In other respects, the data we used are unadjusted. On this point, we share the views of Wallis (1974) and Ghysels (1994) which have shown that the use of adjusted series may introduce distorsions which may lead to misinterpretation of the dynamics of econometric models. Since seasonality is inherent in various economic series, instead of resorting to procedures which eliminate seasonal variations, it is more advisable to deal with unadjusted data.

For unit roots at seasonal frequencies we refer to Watson (1997) work which applied the HEGY procedure on the same data. He concluded to the absence of seasonal root for each variable and explained that, "seasonality counted for very little in the variables probably because quarters in the context of a country like Trinidad and Tobago may not have the meaning as a 4-season country like the USA".

3. Use for forecasting

Our forecasting experiment is based on a selection of models from the classes of models presented in the first section : sims VAR, Litterman VAR, cointegrated VAR and state space model. For each class we chose the better specification according to the importance of their forecasting errors. After this stage we have four specifications that we must now deal with. To carry out this experiment, we divided the sample data into an estimating subsample covering the period 1971 to 1992, and we used the last four years for out-of-sample forecasting.

The first model is an unrestricted VAR (SVAR) that we estimated at order 1 through 8 and then, chose the specification with lag length of 2 which minimize the HQ loss function and leads to the little errors.

The second model is a bayesian VAR (BVAR) with a lag of 8 for each variable. We found that values 0,2 ; 0,5 and 1 for parameters *w*, *z* and *d* are in accordance to Litterman recommandation because these values lead to the model with better performances when considering different models associated with values of *w* varying from 0.1 to 0.9, *z* varying from 0.1 to 0.9 and *d* equal 1 or 2.

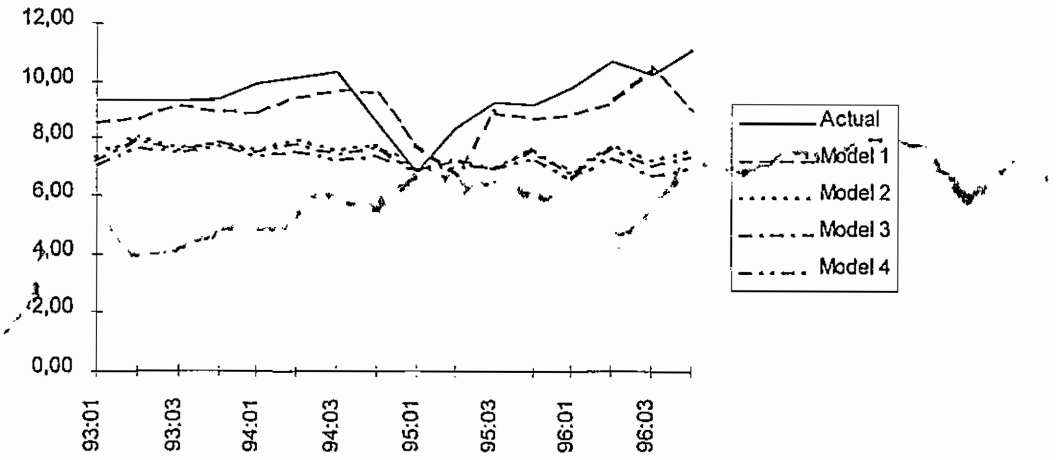
Our third model is a cointegrated VAR (VECM). We estimated it by using an autoregression lag length corresponding to the optimal lag provided by the HQ criterion calculated from the unrestricted VAR. Then we did some tests in order to find the number *r* of cointegrating relationships. The results provided by the Juselius and Hansen (1995) program CATS, which is used as a sub-routine within the RATS software are reported in table 2. For the critical values, we used the statistics of Osterwald-Lenum (1992). These values have been evaluated using the hypothesis that there are linear trends in the levels of the data, and with a model which contain an overall intercept in his short-run part. With the λ_{trace} statistic or the $\lambda_{\max}$ statistic, the hypothesis of one cointegrating vector is clearly accepted at the 95% or 90% significance levels.

Table 2. Tests for the number of steady-state relations in the five-variable system

Ho	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r \leq 4$
Eigenvalues (two lags)	0.4003	0.2326	0.1701	0.0404	0.0305
λ_{trace}	86.92	43.97	21.73	6.07	2.61
$\lambda_{\max}$	42.95	22.24	15.66	3.46	2.61
λ_{trace} critical values (5%)	68.52	47.21	29.68	15.41	3.76
(10%)	64.84	43.95	26.79	13.33	2.69
$\lambda_{\max}$ critical values (5%)	33.46	27.07	20.97	14.07	3.76
(10%)	30.90	24.73	18.60	12.07	2.69

Concerning the state space model, we carried out all the algebraic numerical computation with the Speakeasy software. We have also examined many specifications and have selected the one that has provided the best forecasts. More precisely, we varied the parameters *r* and *f* by giving them values that were between 1 and 4 and estimated associated models.

Figure 1



The best specification is obtained with $r = f = 1$. The Hankel matrix size is 5×5 and the associated singular values :

$$\sigma_i : \quad 2.79 \quad 1.68 \quad 0.272 \quad 0.0128 \quad 0.00189$$

There is a gap from the third value to the fourth value which suggest to retain 3 state variables to adequately synthetize the joint dynamic evolution of the five variables. The estimation results are presented in table 3.

Table 3 : Estimation results for the vector $(y_t, u_t, p_t, d_t, r_t)$

coefficients

$\hat{A}$

0.963	0.0306	0.0417
-0.024	0.967	-0.063
-0.027	-6.5E-4	0.845

$\hat{G}$

0.27	-0.431	-0.437	-0.596	-0.0965
-2.98	0.726	0.451	-0.499	0.253
1.11	-5.46	-0.327	0.485	0.884

$\hat{C}'$

-0.0861	-0.204	-0.722	-0.875	-0.925
-0.134	0.187	-0.06	-0.306	1.29
0.0168	-0.103	0.00202	-0.0308	0.672

covariances

$\hat{\Pi}$

0.968		
0.0038	0.978	
0.0206	-0.0279	0.919

$\hat{\Delta}_e$

0.0019				
8.5 E-4	0.0060			
0.0043	0.0093	0.0338		
0.0072	0.0107	0.0415	0.0598	
-0.0025	0.0111	0.0409	0.0279	0.278

$\hat{\Delta}_0$

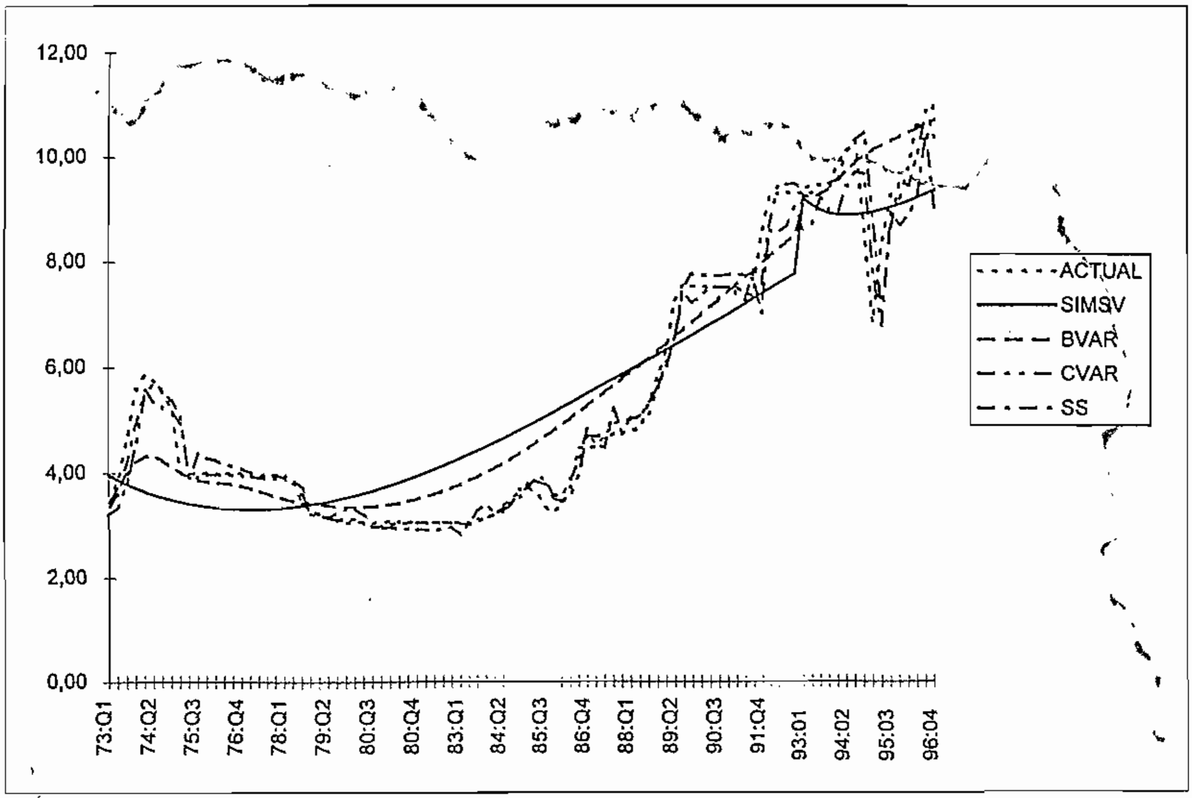
0.0272				
-0.00859	0.0917			
0.0725	0.141	0.542		
0.12	0.131	0.672	0.894	
-0.0833	0.362	0.601	0.4	3.05

The in-sample and out-of-sample forecasting performances are illustrated by figure 2 to figure 6 and are summarized by table 4.

If we examine the evolution of all the variables over the out-of-sample period 1993-1996, the message is clear : Globally, the VECM and SS methods are widely superior than Sims and Bvar mefhods. Indeed, it is not difficult to observe that CVAR and SS methods fit better to change of slopes. Neverthetless, it is not easy to say which of these two methods is better.
The graphical method is not sufficient to see which among the five methods is better. But there are several quantitative criteria that can be used to supplement the graphical approach. We consider four criteria : the MAE, the RMSE and the U1 and U2 Theil statistics. For the GDP and unemployment, we notice a peculiar feature : All the criteria give the same classification.

Plots of Actual and Fitted Values for the five models

Fig 7: Treasury Bill Rate



Plots of Actual and Fitted Values for the five models

Fig 4: Prices

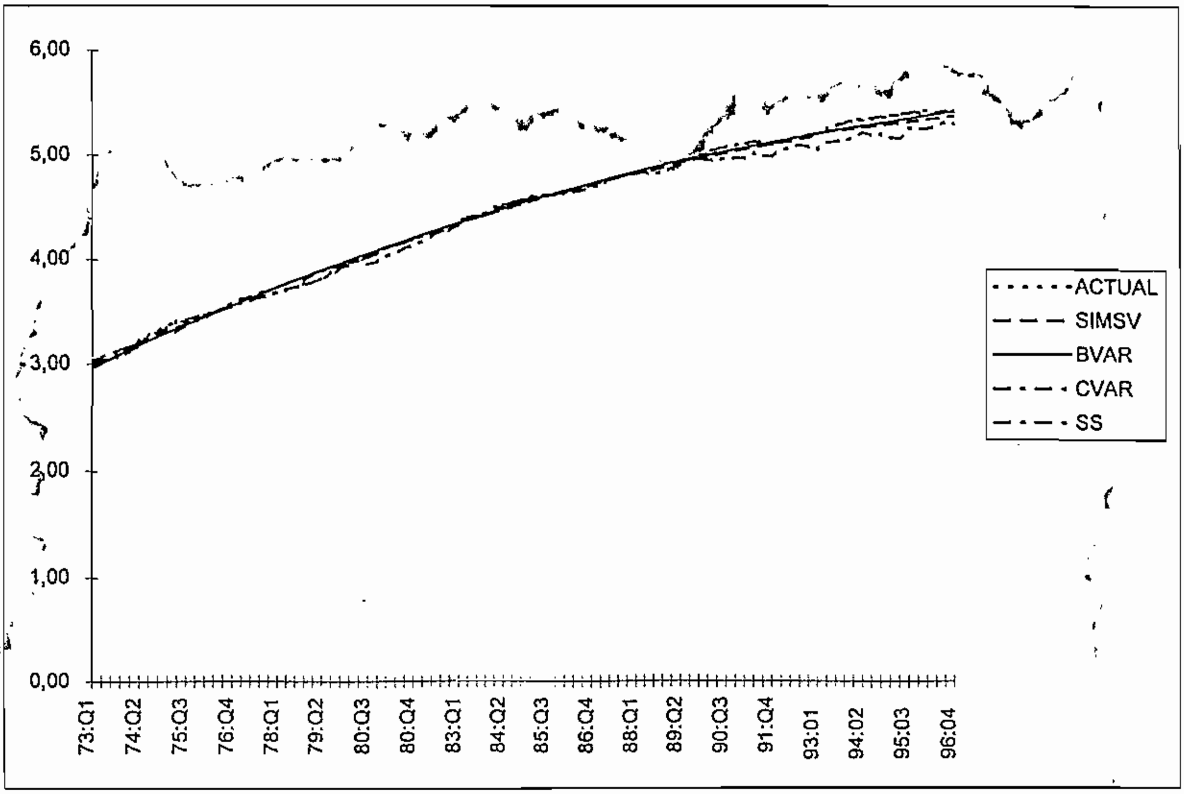
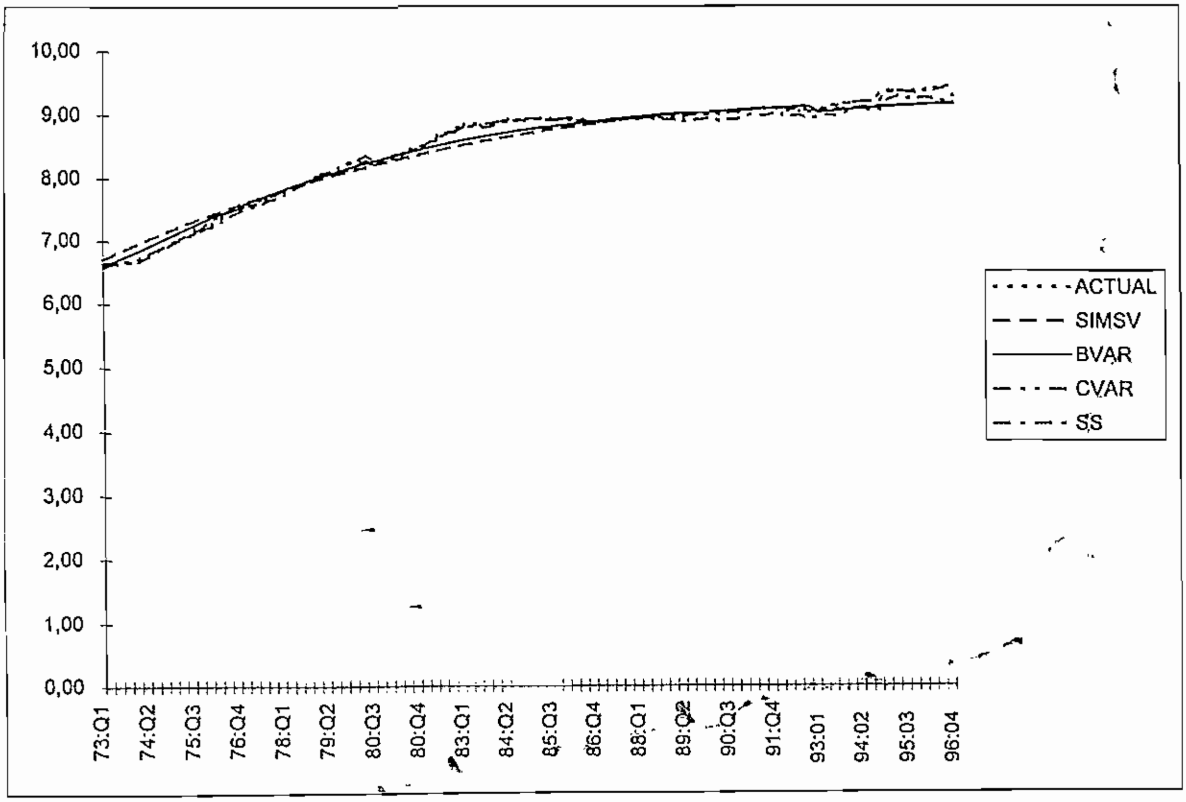


Fig 5: Deposits



Plots of Actual and Fitted Values for the five models

Fig 2: Gross Domestic Product

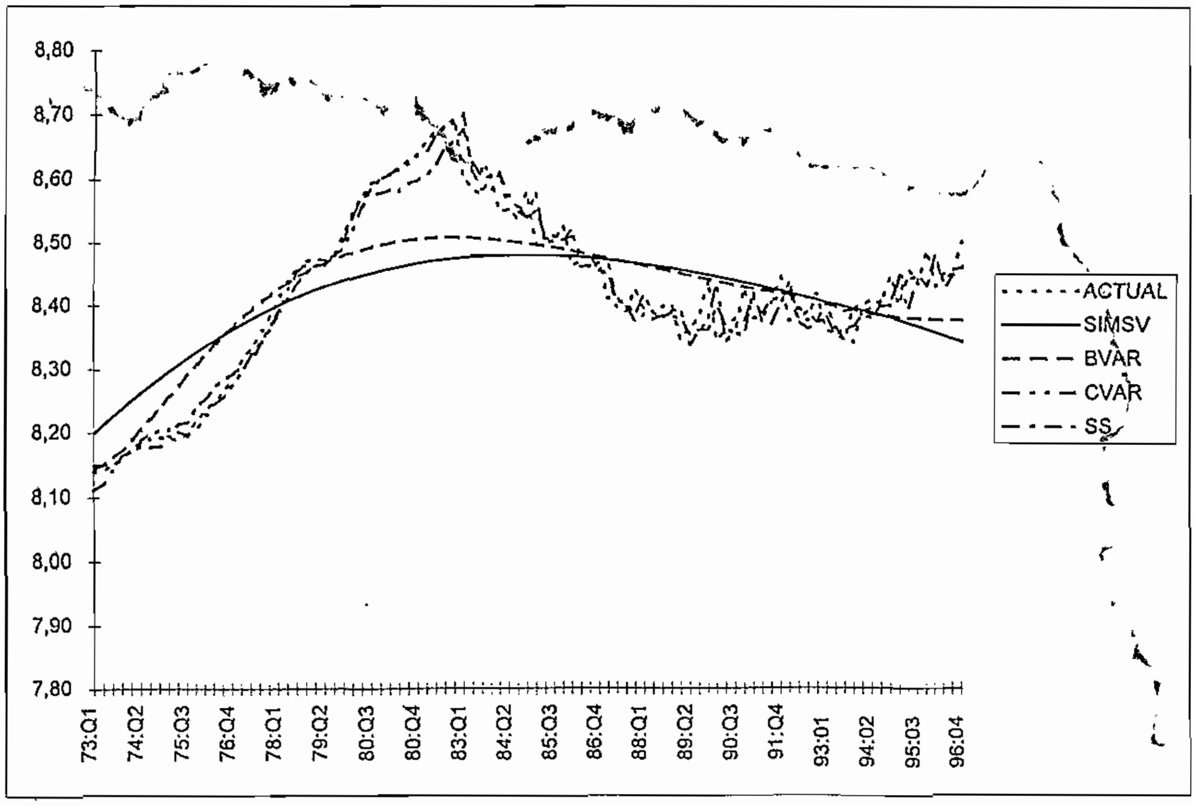


Fig 3: Unemployment

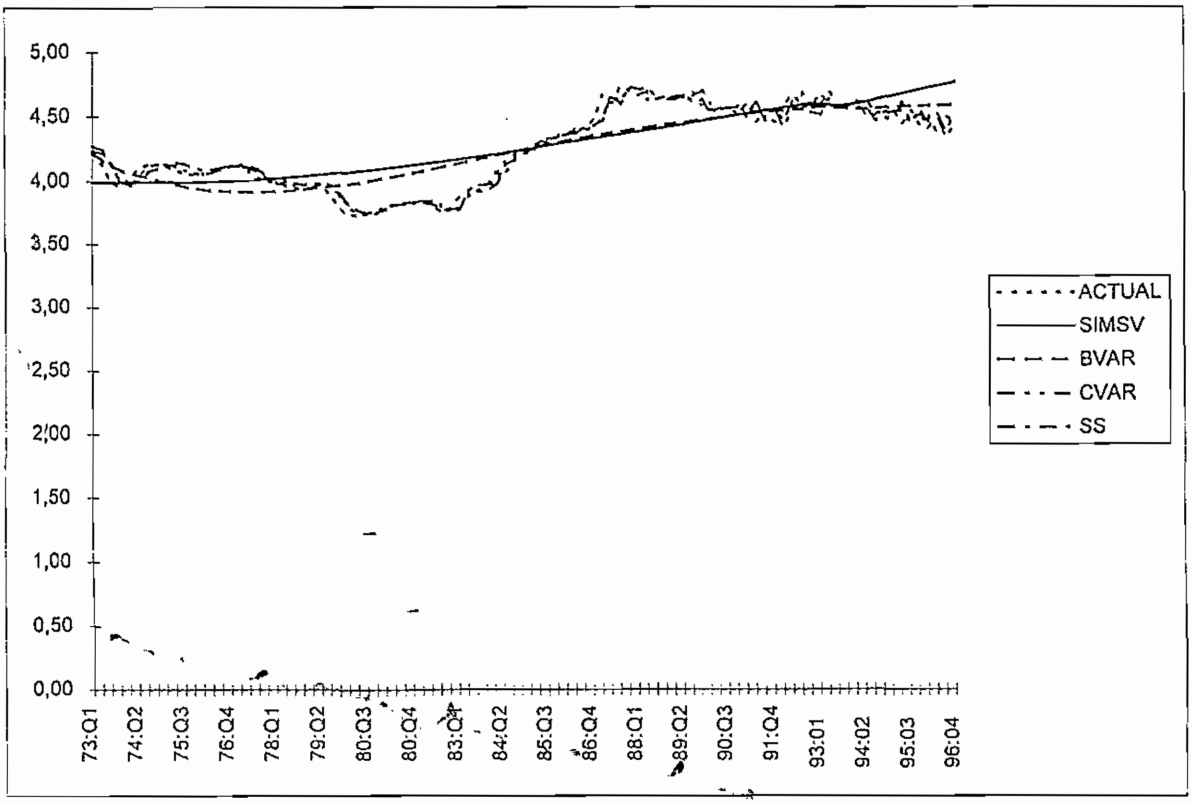


Table 4 : Errors as % of actual, MAE, RMSE, and Theil criteria for out-sample forecasts

	GDP				UNEMP				RPI			
DATE	SVAR	BVAR	CVAR	SS	SVAR	BVAR	CVAR	SS	SVAR	BVAR	CVAR	SS
93:Q1	-0,50	-0,47	-0,50	-0,27	1,60	2,04	1,48	3,34	-0,08	-0,12	-0,14	2,79
93:Q2	-0,58	-0,53	-0,13	0,03	-0,17	0,30	-2,10	-1,10	0,61	0,49	0,55	2,56
93:Q3	-0,63	-0,54	-0,03	-0,20	-0,25	0,24	-0,32	0,12	1,10	0,92	0,33	3,04
93:Q4	0,01	0,04	0,64	0,34	0,25	0,91	0,40	0,51	1,44	1,22	0,18	3,45
94:Q1	0,10	0,14	0,12	0,20	0,29	1,18	0,07	0,98	1,34	1,06	-0,27	2,85
94:Q2	0,25	0,27	0,15	0,35	-2,23	-1,04	-2,43	-1,10	1,34	1,01	-0,18	2,16
94:Q3	0,19	0,20	-0,08	0,03	-2,67	-1,20	-0,36	0,85	1,38	0,98	-0,18	2,97
94:Q4	0,77	0,74	0,55	0,54	-2,61	-0,87	0,15	1,16	1,42	0,95	-0,20	3,00
95:Q1	0,30	0,24	-0,50	-0,55	-2,68	-0,69	0,03	0,88	1,42	0,88	-0,23	3,78
95:Q2	0,97	0,87	0,71	0,15	-5,20	-2,90	-2,25	-3,55	1,55	0,96	-0,04	4,22
95:Q3	0,80	0,66	-0,07	-0,15	-3,49	-0,95	1,92	1,63	1,57	0,92	-0,06	2,64
95:Q4	1,47	1,28	0,62	0,65	-5,96	-3,08	-2,38	-1,67	1,47	0,77	-0,27	2,86
96:Q1	0,88	0,64	-0,58	-0,44	-5,05	-1,93	0,80	1,98	0,86	0,11	-0,84	2,43
96:Q2	1,15	0,85	0,24	0,16	-8,27	-4,77	-3,09	-2,33	0,89	0,10	-0,20	2,17
96:Q3	1,30	0,95	0,13	0,03	-5,54	-1,87	2,48	3,61	0,93	0,09	-0,21	1,80
96:Q4	1,85	1,44	0,45	0,45	-7,01	-3,04	-1,49	0,17	0,96	0,09	-0,27	2,27
AVERAGE	0,0440	0,0360	0,0092	0,0069	0,1365	0,0487	0,0195	0,0163	0,0610	0,0349	0,0069	0,1504
MAE	0,0618	0,0520	0,0290	0,0239	0,1490	0,0757	0,0610	0,0705	0,0615	0,0357	0,0139	0,1504
RMSE	0,0057	0,0038	0,0012	0,0008	0,0344	0,0085	0,0058	0,0074	0,0042	0,0017	0,0003	0,0237
U1	0,0007	0,0005	0,0001	0,0001	0,0076	0,0019	0,0013	0,0016	0,0008	0,0003	0,0001	0,0044
U2	0,1568	0,1049	0,0342	0,0232	0,4642	0,1142	0,0777	0,1000	0,2003	0,0826	0,0139	1,1209

Table 4. Errors as % of actual, MAE, RMSE, and Theil criteria for out-sample forecasts (cont.)

	TOT_DEP				TBR			
DATE	SVAR	BVAR	CVAR	SS	SVAR	BVAR	CVAR	SS
93:Q1	0,26	0,31	0,25	1,13	1,29	0,72	-0,73	7,56
93:Q2	0,64	0,78	0,42	1,38	2,44	0,74	-1,64	6,22
93:Q3	0,77	0,98	0,21	1,79	3,46	0,27	-1,81	1,19
93:Q4	0,91	1,16	0,22	1,78	4,78	-0,36	-1,34	3,95
94:Q1	1,00	1,27	0,18	1,28	10,32	3,49	3,39	9,88
94:Q2	0,79	1,06	-0,16	1,02	12,31	3,85	-0,01	6,81
94:Q3	0,85	1,12	0,06	1,59	13,75	3,96	-0,23	5,87
94:Q4	2,09	2,33	1,19	2,71	-3,99	-17,13	-22,42	-12,88
95:Q1	2,51	2,73	0,36	1,55	-30,90	-48,56	-27,94	-13,91
95:Q2	2,32	2,50	-0,16	0,77	-6,88	-21,83	16,30	19,42
95:Q3	2,01	2,15	-0,12	0,95	2,43	-11,46	6,11	3,57
95:Q4	2,42	2,52	0,45	1,50	1,19	-13,00	-3,69	5,35
96:Q1	2,18	2,22	-0,25	1,01	6,43	-7,09	3,47	9,19
96:Q2	2,56	2,56	0,33	1,74	13,95	1,44	6,72	13,85
96:Q3	2,91	2,84	0,26	2,47	9,31	-3,97	-6,43	-2,02
96:Q4	2,83	2,71	-0,30	1,39	15,91	3,54	6,76	18,97
AVERAGE	0,1579	0,1705	0,0170	0,1397	0,4336	0,5090	0,0800	0,5441
MAE	0,1579	0,1705	0,0286	0,1397	0,8119	0,7400	0,5895	0,8261
RMSE	0,0318	0,0350	0,0014	0,0218	1,0351	1,2677	0,7139	0,9602
U1	0,0034	0,0038	0,0001	0,0023	0,1088	0,1332	0,0750	0,1009
U2	0,7344	0,8093	0,0315	0,5037	1,2045	1,4752	0,8307	1,1173

For the former variable, whatever the criteria considered, the SS method is the best. Then there are the Cvar method , The Bvar method and finally the Sims method. For the last one, the Cvar method seems to be superior. Notice an interesting feature of the criteria : the variation of the error percentage between two methods is nearly the same.

4. Use for economic analysis

Discussions on the effects of economic policy measures are usually held based on a structural econometric model which needs to be solved in order to provide dynamic multipliers. These multipliers describe a variable's response to a shock caused by another variable. To carry out the simulation experiments which are very useful and highly demanded by governments, dynamic multipliers permit to measure the immediate, lagged or long term impact of any exogenous variable's variation on the endogenous variables of a model.

So, if we were to use alternative methods in the absence of structural models, these methods would allow us to calculate the multipliers.

4.1 Shock analysis with VAR models

With the VAR models, these dynamics multipliers are given by impulse functions. The principle is simple. Starting with a specification MA, one can express the variables Y vector by a relationship between present and past errors by

$$Y_t = \varepsilon_t + \psi_1 \varepsilon_{t-1} + \dots + \psi_p \varepsilon_{t-p} + \dots$$

A time $t+s$,

$$Y_{t+s} = \psi_s \varepsilon_t + \psi_{s+1} \varepsilon_{t-1} + \dots + \psi_{s+p} \varepsilon_{t-p} + \dots$$

which allows us to obtain the formula :

$$\frac{\partial Y_{t+s}}{\partial \varepsilon_t'} = \psi_s$$

This equation determines the increase effect by one unity of the innovation of one variable at time t on all the other variables of the system. More precisely, the element situated at the i th row and at the j th column of ψ_s allows to identify the effect of one increase in the innovation ε_{jt} of Y_{jt} on $Y_{i,t+s}$.

The previous formula permits to notice that in the case where we suppose that at time t, ε_{it} varies from δ_i for all i , one can directly obtain the combined effect of all these variations in Y_{t+s}. Indeed, one note that

$$\Delta Y_{t+s} = \frac{\partial Y_{t+s}}{\partial \varepsilon_{1t}} \delta_1 + \frac{\partial Y_{t+s}}{\partial \varepsilon_{2t}} \delta_2 + \dots + \frac{\partial Y_{t+s}}{\partial \varepsilon_{nt}} \delta_n = \psi_s \delta \qquad (7)$$

This formalization shows, however, three inconveniences

i) One can find a multitude of solutions

ii) the error components don't verify the hypothesis of non-autocorrelation and independence since there are links of causality between the variables.

iii) the existence of causality links among the variables does not allow us to interpret the models errors as structural shocks.

Since the researches led by Sims (1980), resorting to the residus orthogonalization by Choleski's decomposition represents a very common method to interpret innovations as indépendant shocks.

Starting with $\varepsilon_t = Sv_t$, and operating in a way that matrix S, considered as the instantaneous matrix of shocks on the endogenous variables should be triangular inferior, this method can identify very simply the impulse sources since it allows to analyse the effects due to the exogeneity of a variable error. Since the innovations must verify $E\{v_t v_t'\} = I$, one must have $SS' = \Sigma$. As this equality contains $\frac{n(n+1)}{2}$ relations, it is necessary to impose $\frac{n(n-1)}{2}$ restrictions at the matrix S to ensure its identification. When the short-term effect of a shock of the variable j on the variable i is insignificant, the must often used procedure is the one proposed by Bernanke (1986) and Blanchard and Watson (1989) who pose that $S_{ij} = 0$.

Among other advantages, Sim's structural VAR allows the identification of various types of shock affecting the system variables. This one provides us very naturally elements to improve our comprehension and we understand better the evolution of macro economic variables. When referring to the abundant literature consecrated to shocks analysed through a VAR model, one can claim that the importance and nature of the various shocks are closely linked to the number of variables which compose the system.
So, Sims was inspired by a model which started with integrating prices in order to show that the adjonction of the variable interest rate to the system reduces significantly the effect of the money on the activity.
From the moment when the shocks partly depend on the retained variables, the choice for the latters becomes important.
This forces us to be careful on the latters' relevancy which seems to be appreciated in a great part from stylised facts, which we must, of course complete by the economic theory.
These few remarks are enough to show how it is helpful to use VAR models since one of its finality is the possibility to check the various alternative economic theories,

The system retained to identify the skocks can be compared with Sim's one. Indeed, Sims used a model with 6 variables: GNP, investment, GNP deflator, money supply, unemployment, treasury bill rate. We considerer a five-variable model in which we can find the same variables except the investment. Another difference to underline is the fact that our model includes employment instead of unemployment. So, we can identify five structural shocks.

- A deposits disturbance easily assimilated as a supply shock coming from a monetary institution as central bank, etc...
- An treasury bill rate innovation. One can consider this latter as a shock coming from an other country.
- An employment innovation apprehended as a conjuctural shock
- A price innovation considered as an inflationist petroleum shock
- An product innovation interpretable, as a productivity shock.

To identify these structural shocks, it is important to take into account restrictions on the matrix S. If the model specification did not impose constraints on S, one could identify fifteen elements. Our specification differs a little from Sims' formalisations, when taking into account that in his structural model, the investment appears, in addition to the five variables composing our model.

Taking into consideration reasonable hypotheses on innovations leads us to consider the following model

$$\begin{cases} \varepsilon_r = v_r \\ \varepsilon_d = a_1\varepsilon_r + a_2\varepsilon_y + a_3\varepsilon_p + v_d \\ \varepsilon_y = a_4\varepsilon_r + a_5\varepsilon_l + v_y \\ \varepsilon_p = a_6\varepsilon_r + a_7\varepsilon_y + v_p \\ \varepsilon_u = a_7\varepsilon_y + a_8\varepsilon_p + v_u \end{cases}$$

These restrictions lead to the matrix form

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ s_{21} & 1 & s_{23} & s_{24} & 0 \\ s_{31} & 0 & 1 & 0 & s_{32} \\ s_{41} & 0 & s_{43} & 1 & 0 \\ 0 & 0 & s_{53} & s_{54} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_r \\ \varepsilon_d \\ \varepsilon_y \\ \varepsilon_p \\ \varepsilon_u \end{bmatrix} = \begin{bmatrix} v_r \\ v_d \\ v_y \\ v_p \\ v_u \end{bmatrix}$$

We can also say that S is a square matix subject to a-prori restrictions which express certain hypotheses on the laus about the model behaviour.
The treasury bill rate is completely autonomous. Another analysis way would have consisted in explaining the rates evolution by the money and GDP.
The second relation is a money demand function. It is the same as Sim's formulation.. Following the example of Barro (1977), it could have been explained by interest rates, employment, the GDP and interpreted as a monetary shock.
The third relation explains the GDP by the treasury bill rate and by employement, a variable which replaces the investment in Sims' formalisation.
The fourth equation explaining the prices can be assimilated to a supply function. Sims adds the investment as an explaining variable.
The fifth equation can be seen as one of Okun's law plus the prices.

On basing our argument about the identification method elaborated by Bernanke (1986) another identification choice is based on the restrictions imposed by the matrix S. Recursivity implies an order and a hierharchy of the variables which indicate that they are those which benefit by precedence on others. We can draw our attention on an alternative model aiming at knowing if the money can be used as the economic policy instrument. The method consists in supposing that the money is exogenous and influences, thus, the short term activity. The formulation retained is the following one.

$$\begin{cases} \varepsilon_d = v_d \\ \varepsilon_p = a_1\varepsilon_d + v_p \\ \varepsilon_y = a_2\varepsilon_d + v_y \\ \varepsilon_{ul} = a_3\varepsilon_d + v_u \\ \varepsilon_r = a_4\varepsilon_d + v_r \end{cases} \Leftrightarrow \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_1 & 1 & 0 & 0 & 0 \\ a_2 & 0 & 1 & 0 & 0 \\ a_3 & 0 & 0 & 1 & 0 \\ a_4 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_d \\ \varepsilon_p \\ \varepsilon_y \\ \varepsilon_u \\ \varepsilon_r \end{bmatrix} = \begin{bmatrix} v_d \\ v_p \\ v_y \\ v_u \\ v_r \end{bmatrix}$$

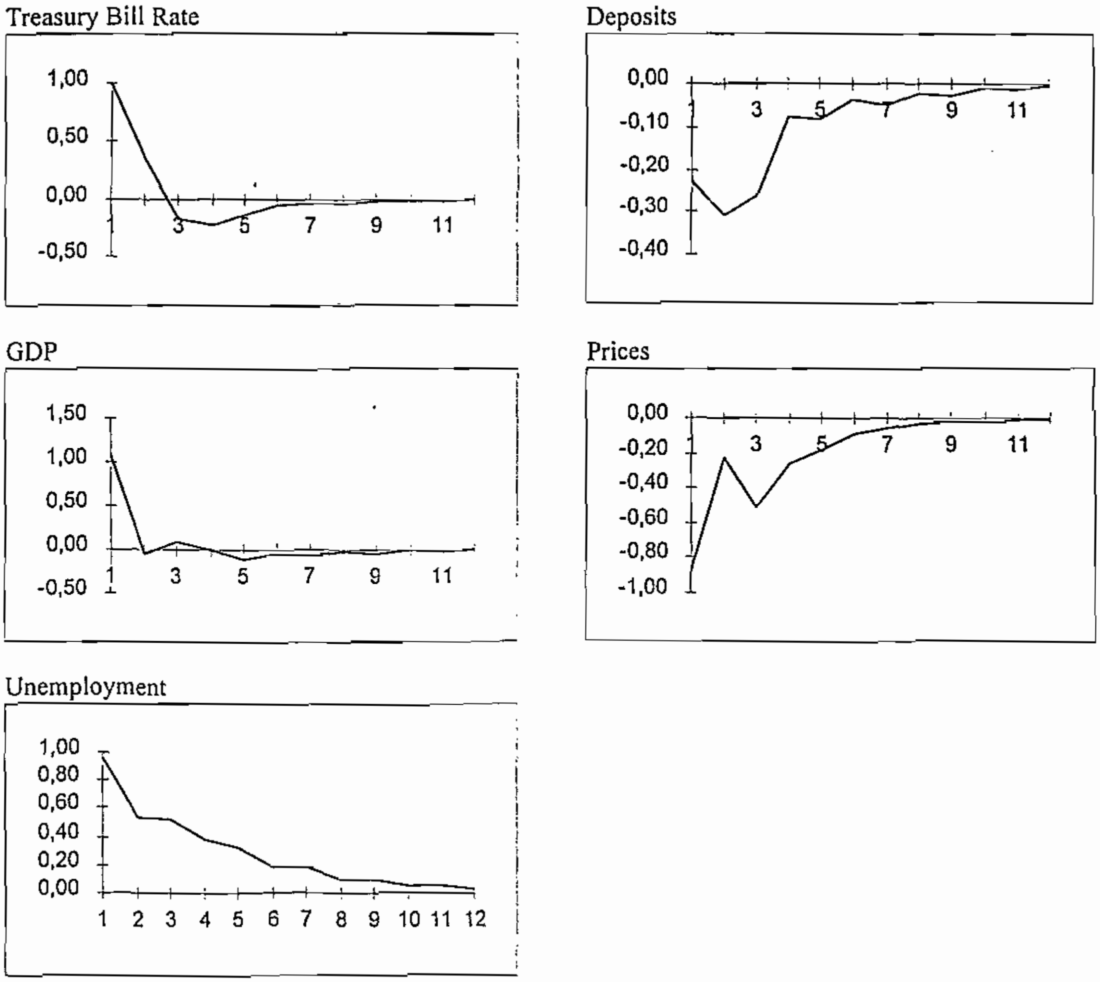
Empirical results

Contrarily to the exercice of forecasting calculus we have carried out the model estimation in considering the whole sample (1971:1-1996:4). The use of Johansen and Hansen (1995) software and the application of Johansen test lead us to accepted the presence of two cointegrated relation. So, we retain a VECM model in order to analyse the shocks. The model describe the variables dynamic evolution in using both short term and long term relations. The short-run dynamics are represented by the first differences and are influenced by the deviation from the long-run behavior relationship.

Responses to a shock to Treasury Bill Rate

Now, we are studying the effects of the treasury bill rate shock on the other variables. This shock is assimilated to a monetary shock.

Figure 7
Impulse Response Fonction for a shock to Treasury Bill Rate

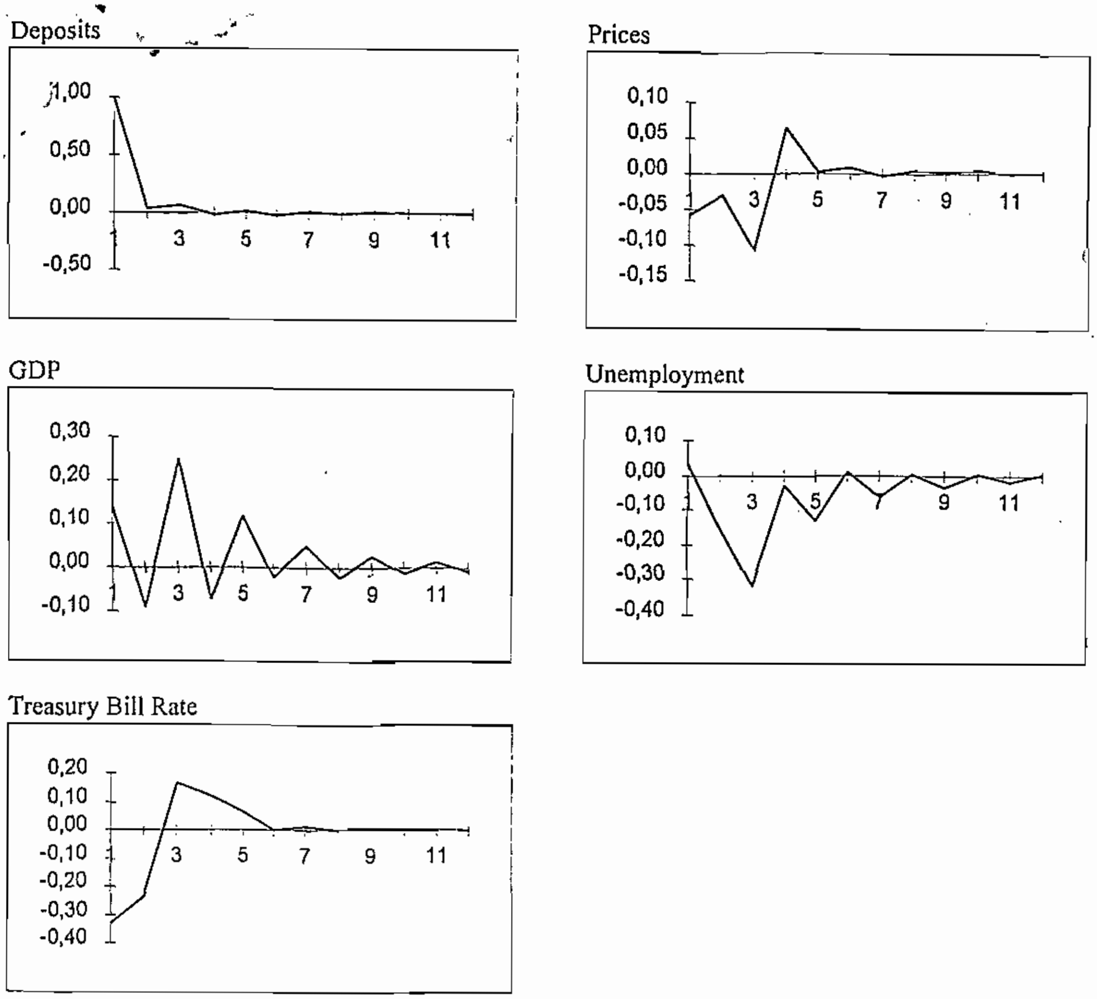


The treasury bill rate uncrease lowers the deposits which reach their lowest level after two periods. The variable "deposits" stays at a level relatively inferior to the considered horizon. This is quite consonant with the IS-LM model. Indeed, though the IS-LM model seems to be lightly set back from the theoretical development that followed it, the Keynes formalism remain very useful for interpreting the monerary policy effects.

The same remark can be applied for the variable prices but it reaches its minimum point after one period. In accordance with the money quantitative theory, it is normal to observe a GDP decrease. Nevertherless after about one period and a half, this decrease is not significant.

During the first period, the unemployment rate increase seems to be the same as GDP one. After a nearly indentical incease, the effect of the TBR on unemployment rate is far much longer than the effect on the GDP.

Figure 8
Impulse Response Fonction for a monetary shock (with deposits)



4.2 Shock analysis with state space models

Concerning state models, in the past as well as recently, econometric literature has evidently shown what system theory has contributed to the analysis and resolution of problems related to policy-making. Control theory offers different strategies to determine optimal trajectories for the policy variables. Furthermore, compared to traditional econometric approach, it allows for a qualitative analysis of the models. Particularly, by bringing about a dynamic generalisation of the Tinbergen and Theil static theory, it provides well-grounded concepts to check the existence, unicity, and faisability of an economic policy. It is well-known that these dynamic properties can be properly characterized using the stability, the commandability and observability criteria.
Before attempting to evaluate an economic policy, it is best to verify, beforehand, if these conditions have been met. The following step often consists in obtaining the dynamic multipliers

that represent quantitative measures of the system reaction when this policy have been put into place.

We obtain these multipliers by introducing the lag operator in the transition equation of the system (4) :

$$z_t = ALz_t + Ge_t$$

which allows to write

$$z_t = [I - AL]^{-1} Ge_t$$

After we consider the observation equation :

$$y_t = C[I - AL]^{-1} Ge_t$$

We find thus a relation in which the observeation variables are directly linked to the innovations by the matrix $C[I - AL]^{-1}G$ which is well know as the transfer matrix in system theory.

Introduicing the result $[I - AL]^{-1} = \lim_{T \to \infty} \sum_{i=0}^{T} A^i L^i$, il follows the relation (8) which provide the dynamic multipliers :

$$y_t = C\left(\sum_{i=0}^{T} A^i L^i\right) Ge_t \qquad (8)$$

However, when the series are not stationary, a second estimation step is because the shock analysis must be based on detrended data. By a aprtition of the eigenvalues one can distinguish the slow dynamics modes associated to the trend and the fast dynamics modes associated with the business cycle. Therefore, one can define a new coordinate system based on the subspaces of the corresponding eigenvectors spanned by matrices P (slow dynamics) and R (fast dynamics). This decomposition yields for the state vector $z_{t+1} = P\tau_t + Rx_t$ and then $y_t = CP\tau_t + CRx_t + e_t$. With the system matrices estimated on initial data, one can define the errors $y_t^c = y_t - CP\tau_t = CRx_t + e_t$ and consider that they are generated by the system

$$\begin{cases} \tau_{t+1} = A\tau_t + Gy_t^c \\ y_t^c = C\tau_t + y_t^c \end{cases} \qquad (9)$$

The second step consist to run the same procedure on the system

$$\begin{cases} x_{t+1} = Fx_t + Je_t \\ y_t^c = Hx_t + e_t \end{cases} \qquad (10)$$

Once the system matrices in (10) are estimated, the sequence of dynamic multipliers are defined by $M_k = HF^k J,\ k = 0,1,2,\ldots$ For their interpretation, we can report to Aoki (1987) : "the *j-th* column vector of the matrix M_k shows how the the current observation is affected by an exogenous impulsive disturbance to the *j-th* component of the data vector of *k* period ago".

The results are the following :

$$F = \begin{pmatrix} 0.883 & -0.0406 & 0.0171 \\ 0.133 & 0.627 & -0.135 \\ 0.12 & -0.139 & 0.74 \end{pmatrix},\quad J = \begin{pmatrix} 1.13 & 6.65 & -16.3 & 3.29 & 0.0576 \\ -22.5 & -9.93 & 1.95 & 12.7 & -0.654 \\ -5.18 & -5.04 & 20.5 & -5.2 & -1.71 \end{pmatrix},\quad H = \begin{pmatrix} 0.00591 & -0.00967 & -0.00419 \\ -0.00906 & -0.0224 & -0.0143 \\ -0.0394 & -0.00855 & 0.0186 \\ -0.0267 & 0.0257 & -0.0179 \\ -0.117 & -0.118 & -0.0886 \end{pmatrix}$$

$$\Omega = \begin{pmatrix} 7.13 & & & & \\ -5.08 & 28.7 & & & \\ 0.0806 & 0.413 & 4.31 & & \\ 2..93 & -1.56 & 0.924 & 10.9 & \\ 7.42 & -46.5 & 7.08 & -6.24 & 684 \end{pmatrix} \times 10^{-4}$$

$$Eig(F) = \{0.548,\ 0.814,\ 0.887\}$$

Conclusion

At the end of this paper, we notice that our results are consonant with the growing concern that state space models will be more and more used to study and forecast evolution of economic variables. Indeed, in the context of forecasting, performances of state space models are highly superior to those of the VAR models except for the VECM. But one can underline that, even with the error-correction representation, VECM models generate forecasts errors which are comparable to those of state models.

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