4. FORECASTING BASED ON OPEN VAR MODEL

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Abstract

Considering as a starting point certain advantages and limits of the VAR model, we propose an opening to include some approaches suggested particularly by economic theory, such as economic policy role and that concerning corrections applied to restore an equilibrium state or a forecast error. In order to improve the forecasting quality we introduced in the VAR model certain variables that express previous approaches. The open VAR model was applied to short-time prognoses regarding the main prices in economy (consumer price index, exchange rate, monthly wage, interest rate).

Keywords: interdependence, autoregressive, simultaneous equations model, structural form, reduce form, lagged variables, error correction, test, ex-post forecast, system, intercept parameter, qualitative variable, ex-post forecast

JEL Classification: C32, C53

1. VAR Model - Particularities and Forecast

We are interested in VARs to forecast economic achievements for at least two reasons: a) certain economic evolutions are considered as being elements of an interdependent process; b) the achievements in t-period are regarded as results of t-i previous achievements.

The first reason is also an essential premise for simultaneous equations systems:

$$B \cdot Y_t + CX_i = U_t \qquad (1)$$

where: B is a matrix of current endogenous variables parameters;

C is a matrix of predetermined variables parameters;

Y, X, U are column vectors of endogenous, respectively predetermined and disturbance variables.

The second reason represents a characteristic of lag models and especially autoregressive process of order p as follows:

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$$y_t = a + \sum_{i=1}^{p} b_i y_{t-i} + u_t \qquad (2)$$

where: y - economic variable

a - intercept parameter

b_i - autoregressive parameters

u_t - errors assumed to be uncorrelated random variables with zero mean and constant variance.

Thus, if initially we consider a variable symbolized by y_1, then its level in t-period y_{1t}, following a former achievement in t-1 period, is described by an autoregressive process of order 1:

$$y_{1t} = \beta_0 + \beta_1 y_{1t-1} + \xi_t \qquad (3)$$

If we suppose a mutual relationship between y_{1t} and other variable y_{2t}, so that including the latter in (3) improves the forecast of y_{1t}, then we can agree to complete equation (3) as follows:

$$y_{1t} = \beta_{10} + \beta_{11} y_{1,t-1} + \beta_{12} y_{2t} + \xi_{1t} \qquad (4)$$

The mutual dependence justified a similar equation including y_2 on the left side of equality:

$$y_{2t} = \beta_{20} + \beta_{21} y_{1t} + \beta_{22} y_{2,t-1} + \xi_t \qquad (5)$$

Both variables y_{t1}, y_{2t} included, according to equations (4-5) considered as a whole, describe the structural form of simultaneous equations model.

The forecasts are obtained from the reduced form[1]:

$$y_{1t} = a_{10} + b_{11} y_{1,t-1} + b_{12} y_{2,t-1} + u_{1t} \qquad (6)$$

$$y_{2t} = a_{20} + b_{21} y_{1,t-1} + b_{22} y_{2,t-1} + u_{2t} \qquad (7)$$

that is

$$Y_t = A + B\,Y_{t-1} + U_t \qquad (8)$$

where: A - column vector of intercept parameters

B - matrix of lagged endogenous variables parameters;

U- vector of noise terms.

The explanatory variables in the reduced form (6-7) are represented by lagged or past values of the endogenous variables in the model, so that the reduced form equations are a "vector autoregressive model" of order 1 and denoted by VAR(1). Therefore, it is possible to consider that both time series variables are random and jointly determined

[1] *The reduced form results from the structural form of the model (4-5) whenever every endogenous variable is expressed as a linear of all the lagged endogenous variables (which are considered exogenous in this context).*

and form a forecasting model that captures their dynamic and interdependent relationships (Griffiths, Judge, Carter-Hill, 1993).

According to Sims[2], if there is a true simultaneity among a set of variables, there should not be any a priori distinction between endogenous and exogenous variables (Gujarati,1995).

A general form results as the model (8) is extended to more then two endogenous variables including p-lags:

$$Y_t = A + B_1 Y_{t-1} + B_2 Y_{1-2} + \dots B_p Y_{t-p} + U_t \qquad (9)$$

Certain assumptions are necessary. The error assumptions of the VAR model as a reduced form of simultaneous equations model follow from the structural equation error properties so $E(U_t) = 0$ and, further on, the errors are uncorrelated. The VAR processes are considered stationary (time series including data for each variable may not have trends, neither seasonal patterns, nor variances changing over time, and consequently the least square estimator of VAR's is consistent and approximately normally distributed. Additionally, we take into account the assumption that the random regressors are contemporaneously uncorrelated with the errors. All these ensure that X`X / T converges to a finite, nonsingular matrix (Griffiths, Judge, Carter-Hill, 1995).

For forecasting while being in the final period (T), vectors y_t, y_{t-1} are necessary. We obtain a forecast for one-period ahead:

$$Y_{(T+1)/T} = E(y_{T+1} / y_T, y_{T-1}, \dots) = b_1 y_T + b_p y_{T-p+1} \qquad (10)$$

Forecasts more than one period ahead can be obtained recursively as follows:

$$Y_{(T+2)/T} = b_1 (y_{T+1/T}) + \dots + b_p y_{T-p+2} \qquad (11)$$

2. Advantages and Limits of the VAR Model

With a view to obtain more accurate prognoses, we consider that VAR`s are better than simple or general linear statistical model because the component parts (endogenous and explanatory variables) are believed to interact and that, hence, should be included as part of the economic system. Thus, the VAR model the seems to be closer to economic reality.

Compared to distributed lag models, the advantages of considering the components simultaneously imply that the model may be more parsimonious, includes fewer lags, and the more accurate forecasting is possible because the information set is extended to also include the history of the other variables (Vorbeek-2004).

The comparison of VAR's with structural simultaneous equations is to VAR's advantage, on the one hand, because the distinction between endogenous and exogenous variables does not have to be a priori, and "arbitrary" constraints to ensure identification are not required (Sims,1980). On the other hand, due to the fact that the

[2] *Sims C.A., "Macroeconomics and Reality",* Econometrica *48, 1980.*

variables are the same on the two sides of equalities, in each equation, OLS is a consistent and efficient estimator (Pindyck, Rubinfeld, 1997).

The VAR model approach is not free of criticisms. Thus, it may be considered an a-theoretical model, or to put it better, a representation summarizing the correlations in the data not offering details about determination or about the results of certain interventions in the economic process (LeRoy, 1985). It is also considered that forecasts may be accurate in certain circumstances but it is difficult to recognize such circumstances to avoid errors (Darnel, Evans, 1990).

Our expectations to fully capture the dynamics of the system being modeled deal with a risk as the longer the lags, the greater the number of parameters that must be estimated and the fewer the degrees of freedom. This may also be considered a weakness of VAR's (Pyndick, Rubinfeld, 1997). Moreover, the presence of several lags of the one and the same variable leads to parameter estimates not being statistically significant, possibly due to multicollinearity.

Another problem is generated by the assumption of stationarity although there are circumstances in which certain risks are significant and results from the transformed data may be unsatisfactory (Harvey, 1990).

If we have in view that the "classical" VAR model includes only endogenous variables (with synchronic and lagged values), forecasts lack these influences proceeding from policy variables or exogenous variables with a significant role in future evolutions of the dependent variable.

3. Open VAR Model and Its Field of Applicability

Establishing an optimal typology of economic processes to witch a VAR model is particularly suitable represents a direction for designing a theoretical support and also an adequate framework for obtaining accurate forecasts. The former section of this paper shows, as well represented by VAR's, those ensembles having strong interconnected variables, among which there are direct and indirect causality relationships, synchronically or laggingly manifested. These groups of variables are well known in the economic theory if we have in view: demand – supply; products – currency – prices on the main markets; supply of labor – wage –productivity; export – import – exchange rate, inflation – unemployment and so on.

Of similar importance are the influences of certain variables not belonging to the interconnected group but representing the external environment. Including these variables and especially policy variables and significant exogenous variables[3] as well represents a possible way to improve forecasts. The application presented in the next section includes such a group of variables related to prices (understood in a broad sense): consumer price index, exchange rate, average wage, interest rate. Each price level depends on its previous levels and also on the levels of other inner and outer variables. The interdependence among such variables is confirmed in economic theory. It is also a realistic supposition to consider the significant role of certain

[3] It is not unusual to include certain exogenous variables in VARs. See Pyndick R.S., Rubinfeld, D.L., *Econometric Models and Econometric Forecasts*, Irwin Mc.Grow Hill,1997.

exogenous variables such as: reference rate, open market operations and minimum level of wage in the economy. Certain corrections generated by unbalanced levels (e.g., wage – productivity, inflation - exchange rate) or by changes in the economic conjunction can also be considered to improve final forecasts.

From another point of view, an ensemble of economic variables for which the intensity of interrelations justifies the affiliation to a distinct group included in a "classical" VAR model (as in 6-7) may be considered a close system. But economy as a whole, on both macro and micro level, implies the existence of a control system which exercises its influence through controlled variables to maintain the main qualities of the managed system. Such control variables are integral parts of the environment. The intensity and direction of their utilization depends of the system sensitivity and its quality to be open to the environment commands (Forrester-1973). If certain feed-back mechanisms (including either negative or positive connections, the latter being frequently present in the price area) prevail, this justifies the inclusion of some control variables in the model in order to insure the relative stability of the system.

Both theoretical economic and systemic approaches give us reasons for an open VAR model that includes external influences. Of course, the opening towards exogenous variables offers the possibility to surpass certain limits specified in Section 2. However, we should take into account a risk of weakening some advantages presented in the same section of this paper.

The system of equations (8) in an open variant of the VAR model would be given by:

$$Y_t = A + B\,Y_{t-1} + C\,X_t + U_t \tag{12}$$

where: X -column vector of exogenous variables (policy and error correction variables;

C - matrix of parameter variables.

To maintain as many advantages of VAR's as possible, the following econometric approaches are indicated:

- Granger causality for establishing the direction of significant influences among economic variables;
- more VAR alternatives;
- Akaike criterion and adjusted square R as well, for choosing between specification alternatives and also for limiting the number of lags (Vorbeek-2004);
- ECM model[4] and its particularity of including variables as differences between levels to whom specification is efficient to capture the idea that agents alter their behavior according to "signals" that they are out of equilibrium (Cuthbertson, 1992);
- qualitative elements, if it is thought that certain events will affect economic life leading to a systematic change in the endogenous variables evolutions.

Concerning the last aspect, we consider that a change in the intercept parameter level within a scale of values delimited by $\hat{a}_0 \pm t_{\alpha/2} \cdot \sigma_{\hat{a}_0}$ may be a cautious possibility to

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[4]Error Correction Mechanism represents a way to keep forecasts closer to reality by linking achieved and predicted (target) values. In the same way, a variable can result as a difference between levels of variables that must be in an equilibrium state.

adjust forecasts according to expectations and difficult to measure events. The intercept parameter can be considered a mean value of the dependent variables, due to all influences, other than those generated by explanatory variables included in the regression equation (a strict mathematical interpretation considers that all explanatory variables are zero). A modified level of intercept parameter within its limits of confidence may be accepted as an expected value that quantifies all qualitative influences expected to alter the dependent variable level in future[5].

The direction and intensity of the alteration results, for example, from a research of certain experts' opinions and measured on a Likert scale[6].

This approach can be considered as a possibility to introduce certain signals 'transmitted from the future' (added to those offered by expected values of exogenous variables), besides past signals resulting from time series used in the estimation stage.

4. Application

The structural form of the simultaneous equations model includes four endogenous variables: consumer price index, exchange rate, monthly average wage, interest rate. In a classical form, the VAR model including only endogenous variables should be specified as fallows:

$$IP_t = d_{10} + d_{11} IP_{t-1} + d_{12} ER_{t-1} + d_{13} W_{t-1} + d_{14} IR_{t-1} + u_1 \quad (13)$$

$$ER_t = d_{20} + d_{21} IP_{t-1} + d_{22} ER_{t-1} + d_{23} W_{t-1} + d_{24} IR_{t-1} + u_2 \quad (14)$$

$$W_t = d_{30} + d_{31} IP_{t-1} + + d_{32} W_{t-1} + + u_3 \quad (15)$$

$$IR_t = d_{40} + d_{41} IP_{t-1} + d_{42} ER_{t-1} + + d_{43} IR_{t-1} + u_4 \quad (16)$$

where: IP - consumer price index calculated as a fixed base of Laspeyres type;

ER - exchange rate (lei / €);

IR - interest rate of banks (non-government), lending;

W - wages (the net nominal earnings).

A variant of the estimation, testing and forecasting stages was dedicated to this form of the VAR model for comparing the results with those offered by the open variant[7].

The structural form of the open VAR model is:

$$IP_t = \beta_{10} + \beta_{11} IP_{t-1} + \beta_{12} ER_{t-1} + \beta_{13} W_t + \beta_{14} IR_t + \beta_{15} DWP_{t-1} + \xi_1 \quad (17)$$

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[5] If we agreed an intercept modified level ($\hat{a}_0{}'$) it follows that for a next time period another confidence interval is available so that in the long run in 95 out of 100 cases the confidence interval regarding a modified value for the intercept parameter will contain its true value.

[6] The Lickert scale includes several answer alternatives (to which a corresponding score is assigned) so that every expert can find his/her own alternative and, finally, an average level of scores is calculated.

[7] Results obtained from the classical VAR model were compared with the open VAR model results and the latter offered better results regarding especially RMS and Chow test.

$$ER_t = \beta_{20} + \beta_{21} IP_t + \beta_{22} ER_{t-1} + + \beta_{23} IR_{t-1} + \xi_2 \quad (18)$$

$$W_t = \beta_{30} + \beta_{31} IP_{t-1} + + \beta_{32} W_{t-1} + \beta_{33} MW_t + \beta_{34} DWQ_{t=1} + \xi_3 \quad (19)$$

$$IR_t = \beta_{40} + \beta_{41} IP_t + \beta_{42} ER_{t-1} + + \beta_{43} IR_{t-1} + \beta_{44} RR_t + \xi_4 \quad (20)$$

where: MW - minimum level of wage in economy;

RR - reference interest rate (policy variable);

DWP - difference between social productivity index and consumer price index;

DWQ - difference between index of wages and social productivity index

The reduced form:

$$IP_t = a_{10} + b_{11} IP_{t-1} + b_{12} ER_{t-1} + b_{13} W_{t-1} + b_{14} IR_{t-1} + c_{15} RR_t + c_{16} MW_t + \\ + c_{17} DWP_{t-1} + c_{18} DWQ_{t-1} + u_1 \quad (21)$$

$$ER_t = a_{20} + b_{21} IP_{t-1} + b_{22} ER_{t-1} + b_{23} W_{t-1} + b_{24} IR_{t-1} + \\ + c_{21} RR_t + c_{22} MW_t c_{23} DWP_{t-1} + c_{24} DWQ_{t-1} + u_t \quad (22)$$

$$W_t = a_{30} + b_{31} IP_{t-1} + + b_{32} W_{t-1} + c_{31} MW_t + c_{32} DWQ_{t-1} + u_3 \quad (23)$$

$$IR_t = a_{40} + b_{41} IP_{t-1} + b_{42} ER_{t-1} + b_{43} W_{t-1} + b_{44} IR_{t-1} + \\ + c_{41} RR_t + c_{42} MW_t + c_{43} DWP_{t-1} + c_{44} DWQ_{t-1} + u_t \quad (24)$$

The data were represented by time series consisting of 40 consecutive quarterly averages on the length 1999, quarter I through 2008, quarter IV. The presence of trend in the data (except the variables denoted by DWP, DWQ) is the first problem regarding stationarity. We considered non-stationary time series resulting from a TS process according to DF test (except IP-time series) and considering forecasts made from a more reliable TSP, whereas those made from DSP are sometime very hazardous [8] (Gujarati, 1995).

Estimating and testing parameters for the reduced form equations were solved by means of the Statistica software. In a first phase, we used as input data time series including only 35 cases (so that the last five quarters were kept as a control segment for ex post forecasts). Several variants were tried beginning with the “classical” VAR model (13-16). Other variants can differ according to: the data used (original or stationary data), order of lag, explanatory variables retained (not identical as reduced form (21-24)). The option between variants was based on adjusted square R ($\hat{R}^2$), on Akaike criterion and also on the F-test (global significance), DW-test, t-test. Another criterion was represented by the accuracy of prognosis obtained for the control period (quarter IV-2007, and quarters I, II, III, IV-2008) based on RMS and Chow-test, the latter regarding the stability of parameters. The results of this checking part of the application, for each selected regression function of suitable forecasts, are presented in two variants: A-stationary data; B-original data.

$$IP_t = f(IP_{t-1}, ER_{t-1}, W_{t-1}, RR_t, DWP_{t-1}) \quad (25)$$

[8] Results of a variant based on DSP stationarity time series confirm such an assertion if we have in view test values (F<2,03; square R<0,13,etc).

A (stationary data) $\hat{R}^2$ =0.92; F=79;AIC=6.94; DW=2.78; RMS=0.144; F(Chow)=8.99

B (original data): $\hat{R}^2$ =0.99; F=3097; AIC=6.94; DW=2.83; RMS=0.273 F(Chow)=8.86

$$ER_t = f(IP_{t-1}, ER_{t-1}, W_{t-1}, RR_t, MW_t, DWP_{t-1} DWQ_{t-1}) \quad (26)$$

A) $\hat{R}^2$ =0.9439; F=114.2; AIC=-4.31; DW=1.83; RMS=0.0854; F(Chow)=5.53

B) $\hat{R}^2$ = 0.975 ; F=186; AIC=-4.2; DW=2.41 ; RMS=0.0438 ; F(Chow)=2.28

$$W_t = f(IP_{t-1}, W_{t-1}, MW_t) \quad (27)$$

A) $\hat{R}^2$ =0.8554; F=88; AIC=6.023; DW=2.57; RMS=0.5159; F(Chow)=6.41

B) $\hat{R}^2$ =0.99; F=1629 ; AIC=6.24; DW=2.79 ; RMS=0.0088 ; F (Chow)=4.305

$$IR_t = f(IP_{t-1}, ER_{t-1}, W_{t-1}, IR_{t-1}, RR_t \quad (28)$$

A) $\hat{R}^2$ =0.6334; F=12; AIC=1.545; DW=2.3 ;RMS=0.265 ; F (Chow)=0.89

B) $\hat{R}^2$ = 0.969 ; F=220; AIC=2.04 ;DW=1.884; RMS=0.149 ; F (Chow)=0.33

In a second phase, estimating and testing parameters rely on time series taking into account all the data, so that t=1,2,…,40, and yields the following results:

A) $IP_t = 4.2252 + 0.6743\, IP_{t-1} + 22.4044\, ER_{t-1} - 0.265\, W_{t-1} + 2.9067\, RR_t - 2.7413\, DWP_{t-1}$

t (0.579) (4.08) (0.6911) (-1.598) (1.4118) (-0.0484)

$\hat{R}^2$ =0.85; F=46.3; AIC=7.63; DW=2.09

$ER_t = 0.0135 + 0.00034\, IP_{t-1} + 0.7778,\, ER_{t-1} - 0.0012\, W_{t-1} - 0.0108\, RR_t + 0.0028\, MW_t +$

t (0.627) (0.725) (8.125) (-1.957) (-1.795) (4.145)

$0.0541\, DWP_{t-1} + 0.8296\, DWQ_{t-1}$

(0.321) (1.067)

$\hat{R}^2$ =0.939; F=87; AIC=-4.225; DW=1.98

$W_t = 1.0021 - 0.1242\, IP_{t-1} + 0.7738\, W_{t-1} + 0.346\, MW_t$

t (0.229) (-1.622) (6.069) (2.72)

$\hat{R}^2$ =0.9248; F =161; AIC =6.56; DW=2.9

$IR_t = -0.14 - 0.0087\, IP_{t-1} + 2.8827\, ER_{t-1} + 0.037\, W_{t-1} + 0.2918\, IR_{t-1} + 0.136\, RR_t$

t (-0.426) (-1.125) (1.828) (3.858) (2.3054) (1.4411)

$\hat{R}^2$ =0.8179; F=36.04; AIC=1.519; DW=2.04

Finally, we obtained forecasts following the recursive procedure (10 - 11). For exogenous variables we have in view the main targets claimed by Government for 2009: stability of wage-levels, slow decline in reference-rate, and maintenance of economic equilibriums. Accordingly, we establish a set of values for exogenous variables, as follows:

RR: 10.25 ; 10; 10; 10 ; MW: 600 ; 600; 600; 600; DWP: 0.02; 0.01; -0.02; -0.05; DWQ: 0.2; 0.3; 0.3; 0.4

The forecasts in variant A (stationary data) after including trend and B (original data):

Table 1

Quarter	I	II	III	IV	2009	I	II	III	IV	
	Stationary data					Original data				
IP(%)*:	101.8	102.5	102.4	102.3	(109.5)**	100.9	101.2	100	100.09	(102.3)**
ER (lei/€)	4.28	4.55	4.61	4.37		3.56	3.91	3.41	2.98	
W (lei)	1453	1483	1513	1540	(8.3%)**	1488	1551	1609	1663	(17%)**
IR (%)	18.15	19.36	19.1	18.5		20.5	21.82	24.19	24.68	
IP (%)***	101.3	102.2	102.2	102.2	(108.3)**					

*Note: *) percentage in quarter t as compared to previous quarter;*
***) percentage in quarter IV 2009 as compared to IV 2008;*
****) forecast based on a modified value of intercept parameter $\hat{a}_0'$ = -10.*

A comparison between the prognosis obtained in both variants is favorable to variant A (stationary data) as it is more realistic. To confirm such an option and also to consider certain qualitative influences as news, targets, expected events, we point out some signals received in the first months of the year 2009: eventually, the inflation will be around 4.5%; the exchange rate between 4.3 and 4.6 lei/€; the wages will register slow increases (around 5%); interest rate must decrease to 15 %-20%. Our forecasts indicate for the last quarter of 2009 a rate of inflation around 9.5%, an increase in average wage by 7.6% and exchange and interest rates around expected levels. If we agreed upon an optimistic variant regarding inflation (lower than 9.5%), then we would accept a modified value of the intercept parameter as a result of certain symmetrical influences that would stabilize the future levels of consumer prices. As a consequence, a modified value is placed on the left side of the interval $\hat{a}_0 \pm t_{\alpha/2} \cdot \sigma_{\hat{a}_0}$, that is between 4.2282 – 2.44 x 7.379 = - 13.78 and 4.2282 + 2.44 x 7.379 = 22.22. We established $\hat{a}_0'$ = -10. This change of intercept parameter will be propagated by the recursive forecast procedure. A new set of forecast results is obtained but it is not very different as compared to our forecast written on the left side of Table 1.

Summary

For those economic processes that include certain intensive interconnected variables, the VAR model can be considered a suitable representation.

An opening of this model with a view to include a limited number of external influences makes possible, on the on hand, closeness to the economic facts and, on the other hand, an increased accuracy of forecasts based on several factors. In economy the main external influences occur from the policy area, the attempts to maintain economic equilibriums, economic context.

Including some exogenous variables corresponding to such influences, removes some limits of the VAR model, but weakens its advantages. A way to improve the forecasting framework consists in elaborating several variants of the model and "check, check and check again" (Johnston, 1995). Therefore, to forecast the main prices evolution (consumer price, exchange-rate, wages, interest rate), we elaborated several variants of the VAR model and, finally, a variant we named open VAR model was retained. It includes a limited number of exogenous variables. Short time forecasts are the most suitable, and a constant updating is recommended.

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