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VAR MODELS FOR ECONOMIC POLICY TARGETS OF OECD COUNTRIES IN 1990-2016. ASSUMPTIONS AND ESTIMATION RESULTS

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Abstract: Paper presents estimation results of three-equational VAR models separate for every of 34 OECD countries. The variables of every model are economic policy targets: GDP growth rate, unemployment rate and inflation rate. Quarterly data for period 1990 – 2016 were used. Special attention has been given to analysis of cause-effects relationships and random fluctuations.

Keywords: economic policy targets, VAR models

INTRODUCTION

The aim of the paper is to present the objectives, methods and results of the analysis using empirical vector autoregressive (VAR) models of the relationships between the three, most often applied in practice, macroeconomic policy targets: GDP growth rate and unemployment and inflation rates, separately for each OECD country on quarterly data in the period: first quarter 1990 to first quarter 2016.

Economic theoreticians devoted special attention to dependencies between every two of the above mentioned economic policy targets [Juselius 2006]. In these respects the Okun's curve (the relationship between the GDP growth rate and unemployment rate) [Okun 1962], the Phillips curve (the relationship between inflation and unemployment rates) [Phillips 1958], and aggregate supply curve [for

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instance, Błaszczuk 2015a] have been studied both theoretically as well as empirically.

These three concepts Błaszczuk [2015b, 2015c] combined into one model. Namely, the simultaneous relationships between every two targets were determined and analysed, firstly. On these bases, the three-equational general equilibrium (B) model has been constructed and solved yielding the long term equilibrium point.

The present analysis is a continuation of researches carried out by Błaszczuk [2015b, 2016] since 2013. However, a different idea in relationships between economic policy targets modelling is behind the VAR models. Essential *novum* in the present analysis is study of dynamic dependencies between all three analysed variables. Namely, formulating VAR model of an economic system one assumes that "everything depends on everything". In other words, every of n variables is explained as a function of $n \times p$ lagged variables (where p is the number of delays) and, possibly, of selected deterministic variables. Therefore, in the formulation of the VAR model one *a priori* does not take into account either economic theory assumptions or dependencies observed in practice. However, the latter relationships influence the structure of the subsequent VAR model versions at the stage of its (economic and/or statistical) verification if one does not stop on the estimation of a "full" version, in which in every equation all $n \times p$ variables are present. Eventually one obtains dynamic cause-and-effect relationships between every non-lagged variable and the all lagged ones. However, unlike in case of dynamic structural models, one does not interpret the estimates of VAR model parameters. Contrary, the response of every variable on the shock change of every of the other variables is examined. In the following paragraphs of the paper we: 1) show the basics of VAR modelling, 2) present and discuss results of our empirical analysis, 3) characterise directions of further researches.

VAR MODELLING

In the seventies of the last century large structural models had been constructed. They were criticised because [Sims 1980] that they forced to accept *a priori* a number of assumptions about the nature of the analysed relationships for which the compelling arguments were often lacking and because [Lucas 1976] they were hardly applicable in practice. Sims has suggested substitution of the structural models by vector autoregressive ones. Their concept is characterised by: (a) joint modelling of all the analysed variables, (b) lack of division on the endogenous variables and the exogenous ones, (c) no zero conditions, (d) rich dynamic specification of the model, (e) good forecasting and simulation properties. The principle of VAR modelling is to estimate the models on stationary data.

VAR model of the order p for n-dimensional vector of variables $\mathbf{Y}_t = [Y_{1t}, ..., Y_{nt}]^T$ is given by the formula:

$$\mathbf{Y}_t = \mathbf{A}_0\mathbf{D}_t + \sum_{i=1}^{p}\mathbf{A}_i\mathbf{Y}_{t-i} + \boldsymbol{\varepsilon}_t = \mathbf{A}_0\mathbf{D}_t + \mathbf{A}_1\mathbf{Y}_{t-1} + \mathbf{A}_2\mathbf{Y}_{t-2} + \ldots + \mathbf{A}_p\mathbf{Y}_{t-p} + \boldsymbol{\varepsilon}_t, \tag{1}$$

where n-dimensional random factor $\boldsymbol{\varepsilon}_t$ is subject to the following assumptions: $\boldsymbol{\varepsilon}_t \sim N(0,\Sigma)$ and $Cov(\boldsymbol{\varepsilon}_t, \boldsymbol{\varepsilon}_s) = 0$ for $t \neq s$, and $\mathbf{A}_0\mathbf{D}_t$ is the deterministic part of equation (for example, trend).

The VAR model equations may be estimated one by one using OLS or all together using MLE. In the absence of theoretical justification on row of lags (p) one can rely on the statistical properties of the model [Lütkepohl 2005, Juselius 2006]. Then the most common used are criteria: AIC, SIC, HQC. Another possibility in this respect is the analysis of residuals. Random variables of every equation should be characterised by lack of autocorrelation (to check this one can use Box - Pierce statistic or Ljung - Box one). Hypothesis about the lack of multidimensional autocorrelation of random variable can be tested with the help of the Breusch - Godfrey test. An indication for the choice of the maximum delay can also be the results of significance tests for the recent delays [Kusideł 2000, Wójcik 2014]. One should also remember that in practice, in order to estimate the model parameters properly, a large number of observations is required.

While verifying VAR model a special attention is paid to the analysis of causality. In accordance with the definition, the variable Y_2 is the cause of Y_1 in sense of Granger, if the current values of Y_1, can be predicted with greater precision, *ceteris paribus*, using past values of the Y_2 than without their use [Charemza & Deadman 1997]. The Granger test for causality is as follows. Let

$$Y_{1t} = \sum_{i=1}^{p}\alpha_i Y_{1,t-i} + \sum_{j=0}^{q}\beta_j Y_{2,t-j} + \varepsilon_t\,. \tag{2}$$

Null hypothesis: $H_0 : \beta_0 = \beta_1 = \ldots = \beta_q = 0$, so there are no one-way causal dependencies between Y_2 and Y_1, i.e. Y_2 is not the cause of Y_1. Test statistics for large samples converges to the $\chi^2(q)$ distribution.

Estimates of the VAR models parameters one does not interpret. Instead, one interprets all of the estimated parameters simultaneously by calculating the impulse response function (IRF). IRF reflects the dynamic (in k periods) response of the endogenous variable Y_i on the change of the j-th random variable (ε_j):

$$\mathrm{IRF}(i,j,k) = \frac{\partial Y_{i,t+k}}{\partial \varepsilon_{jt}}\,. \tag{3}$$

Analysis of the impulse response functions is a standard approach in the VAR modelling to study the reaction of the economic systems to shocks.

RESULTS OF INVESTIGATION

Sources of statistical data

In the analysis we used quarterly data on the GDP growth rates (*rGDP*), unemployment rates (*HUNR*) and the inflation rates (*CPI*) in all (34) OECD countries during the period 1990Q1 – 2016Q1 [http://stats.oecd.org/ (access 1.05.2016)].

Specification of the VAR models

In accordance with the purpose of the study, we decided to build comparable vector autoregressive models for individual OECD countries based on their historical data on *rGDP*, *CPI* and *HUNR*.

In our study we used nonstationary data because of the two circumstances. First, we obtained stationary data for various differences for different variables for different countries. Thus, comparing, computed on such data, relationships between the analysed variables for different countries would not be very meaningful, if reasonable at all. Secondly, we inputted deterministic variables taking into account time (t and t^2) and seasonality (Q_1, Q_2 and Q_3) thus eliminating to a large extent both non-stationarity and autocorrelation of random variables.

To determine the optimal order of lags we used, separately for every model, the AIC, SIC and HQC information criteria. In the vast majority of cases lags were rather small: 1 quarter: 10 countries; 2 quarters: 15 countries; 3 quarters: 4 countries; 4 quarters: 3 countries (see Table 1).

Table 1. VAR models types for OECD countries

VAR model type	Number of countries	Countries
VAR (1)	10	Belgium, Chile, France, Hungary, Israel, Italy, Japan, Korea, New Zealand, Slovenia
VAR(2)	15	Canada, Czech Republic, Denmark, Finland, Germany, Greece, Iceland, Ireland, Luxembourg, Netherlands, Norway, Slovakia, Sweden, United Kingdom, USA
VAR(3)	4	Australia, Mexico, Poland, Switzerland
VAR(4)	3	Estonia, Portugal, Spain
VAR(5)	1	Austria
VAR(8)	1	Turkey

Source: own calculations using the *gretl* package

The analysis of causality

In the majority of cases we identified one-way and/or two-way causalities. Bidirectional dependencies occurred particularly frequently between unemployment rate and the GDP growth rate. Just almost as often were one-way dependencies: unemployment rate → inflation rate, the GDP growth rate → unemployment rate, and a little less often: inflation rate → the GDP growth rate and the GDP growth rate → inflation rate (see Table 2).

Table 2. One-way and/or two-way causalities in the 34 OECD countries VAR models (the significance level 10%)

Causality between			Number of countries	
CPI	↔	*rGDP*	2	21
	→		10	
	←		9	
HUNR	↔	*rGDP*	14	30
	→		3	
	←		13	
HUNR	↔	*CPI*	6	25
	→		15	
	←		4	

Source: own calculations

We discovered the lack of causal dependencies for all three pairs of variables only for Slovakia. There was causal dependence of for only one pair of variables: (a) *HUNR* ↔ *rGDP* in case of: Slovenia, the Czech Republic, Ireland, (b) *HUNR* → *CPI* in case of Norway, (c) *CPI* ← *rGDP* in case of Luxembourg.

Table 3. The causal dependencies for all the three pairs of variables

Country	Causal dependency type		
	CPI **?** *rGDP*	*HUNR* **?** *rGDP*	*HUNR* **?** *CPI*
Poland	↔	←	→
Japan	←	↔	↔
Austria	←	↔	→
Belgium	←	↔	→
France	←	↔	→
Mexico	←	←	↔
Turkey	←	←	→
Korea	→	↔	→
Finland	→	←	→
Israel	→	←	→
Greece	→	↔	←
Spain	→	↔	←
United	→	←	←
Iceland	→	→	↔
Australia	→	→	→

Source: own calculations

The causal relationships for two pairs of variables occurred for the larger groups of countries: (a) *HUNR* and *rGDP*, *HUNR* and *CPI* in case of: Canada, the Netherlands, Germany, Italy, Hungary, New Zealand, Sweden, (b) *CPI* and *rGDP*, *HUNR* and *rGDP* in case of: Denmark, Chile, Estonia, USA, (c) *CPI* and *rGDP*, *HUNR* and *CPI* in case of Portugal.

The causal dependencies for all three pairs of variables have been observed in up to 15 countries. In Table 3, there are five groups of countries with similar nature of causative dependencies between the analysed variables. In the first group we discovered influence of the GDP growth rates on inflation rates, two-ways relationships between *HUNR* and *rGDP*, and the impact of unemployment rates on the inflation rates. In the second group, there is the influence of the GDP growth rates on inflation rates and unemployment rates. Third group of countries is characterized by the impact of price level changes on the GDP growth rates, GDP growth rates on the unemployment rates and the unemployment rates on the inflation rates. Only the last relationships are reversed in the fourth group of countries when compared with the third one. The economies of the fifth group tend to be in their reactions unlike the other countries concerned.

All the discovered causal dependencies are shown in Table 4. The names of countries characterized by appropriate bi-directional causality are typed in bold.

Table 4. OECD countries by causal dependencies between analysed policy targets

→	*rGDP*	*CPI*	*HUNR*
rGDP	X	Austria, Belgium, Chile, Denmark, France, Japan, Luxembourg, Mexico, **Poland**, **Portugal**, Turkey	**Austria**, **Belgium**, **Canada,** Chile, **Czech Rep.**, **Denmark**, Estonia, Finland, **France**, **Germany**, **Greece**, Hungary, **Ireland**, Israel, Italy, **Japan**, **Korea**, Mexico, **Netherlands**, New Zeeland, Poland, **Slovenia**, Sweden, Turkey, United Kingdom, United States
CPI	Australia, Estonia, Finland, Greece, Iceland, Israel, Korea, **Poland**, **Portugal**, Spain, United Kingdom, United States	X	**Canada**, Germany, Greece, **Iceland**, **Italy, Japan**, **Mexico**, **Netherlands**, Spain, United Kingdom

→	*rGDP*	*CPI*	*HUNR*
HUNR	Australia, **Austria**, **Belgium**, **Canada**, **Czech Rep.**, **Denmark**, **France**, **Germany**, **Greece**, Iceland, **Ireland**, **Japan**, **Korea**, **Netherlands**, **Slovenia**, **Spain**, Switzerland	Australia, Austria, Belgium, **Canada**, Finland, France, Hungary, **Iceland**, Israel, **Italy, Japan**, Korea, **Mexico**, **Netherlands**, New Zeeland, Norway, Poland, Portugal, Sweden, Switzerland, Turkey	X

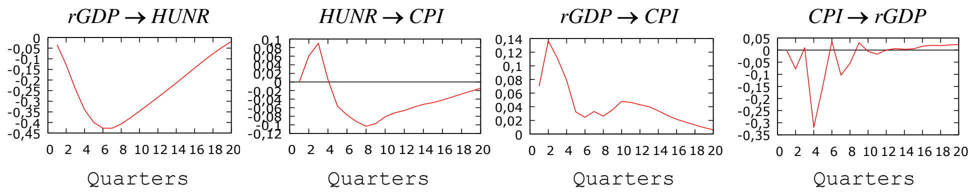
Source: own calculations

Summing up, we found causal dependencies for all the three pairs of variables for about half of the analysed countries, and for only a little less number of countries we stated causal dependencies for two pairs of variables. The most influencing and the most influenced variable was unemployment rate (17 + 21 cases and 26 + 10 cases, respectively) and the smallest influence had inflation rate (12 + 10 cases) while the least influenced – the GDP growth rate (12 + 17 cases).

The impulse response analysis

Then, based on the estimated equations we found the impulse response functions. We analysed obtained functions for all the countries and next classified them into "strategic groups". Then (because of shortage of space in the paper) we selected for further discussion one country only from every group with the relationships between all the three variables (see Table 3).

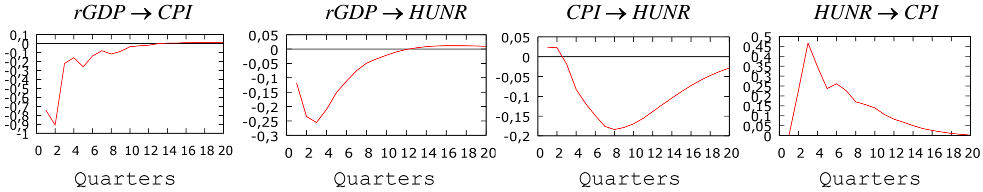
Figure 1. Impulse response functions for Poland



Source: own calculations

From the first group we have chosen Poland. In this country an increase of the GDP growth rate caused initially gradual decreases in unemployment rates down to more than 0.4% in the seventh quarter and then gradual return to reach the initial situation in the twentieth quarter (cf. Figure 1). On the other hand the increase in the unemployment rate invoked inflation rates rises during the first three quarters up to 0.09%, then their fall during the next five quarters down to -0.1%, and finally their return to the initial situation, perhaps in the end of the sixth year after the shock. The rising *rGDP* caused an increase of inflation in the second quarter, but the rising *CPI* was associated with an decrease of *rGDP* in the fourth quarter.

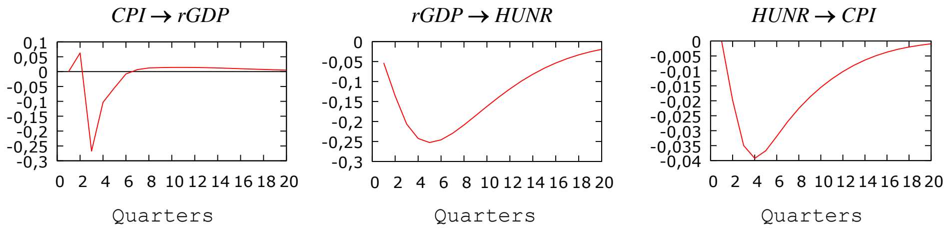
Figure 2. Impulse response functions for Mexico



Source: own calculations

In Mexico, the country from the second group, an increase of the GDP growth rate caused initially decreases in the inflation rate and in the unemployment rate in the second quarter (cf. Figure 2). The rising inflation rate was associated with a fall in unemployment.

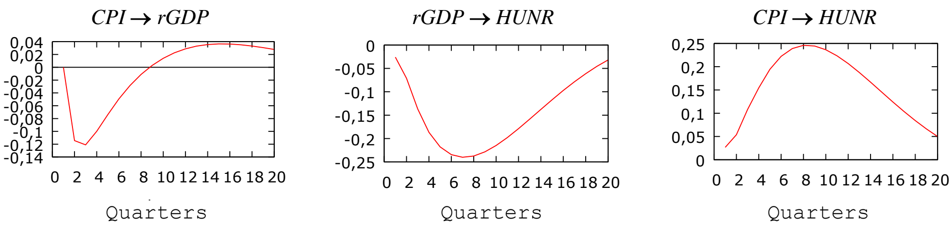
Figure 3. Impulse response functions for Finland



Source: own calculations

Other shapes have the respective functions for Finland which belongs to the third group (cf. Figure 3). For this country an increase of inflation caused decline in the GDP growth rates down to 0.25% in the third quarter, the decline in the GDP growth rates resulted in an increase in the unemployment rates up to 0.25% in the fifth quarter and rising unemployment rates were associated with a fall in inflation rates down to 0.04% in the fourth quarter. The recovery of the GDP growth rates took about a year while of the other two variables about 4 years.

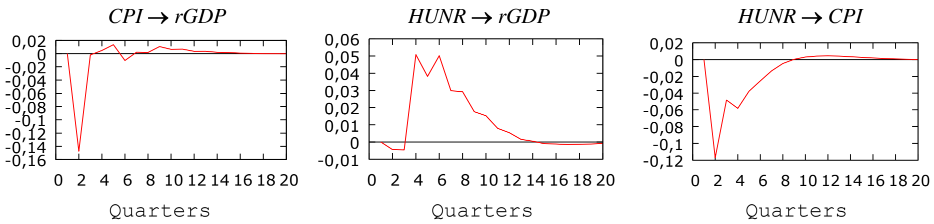
Figure 4. Impulse response functions for United Kingdom



Source: own calculations

From the fourth group we chose United Kingdom. The effect of inflation rate shock on the GDP growth rates and of the GDP growth rate on unemployment rates in this country are somewhat similar to that of Finland (cf. Figure 4). The recovery of the GDP lasted, however, 1½ years but thereafter there was the long lasting increase of the GDP growth rate by almost 0.04%/quarter during, probably, 3½ years. The decrease of the GDP growth rates caused similar increases of unemployment rates as in Finland but they lasted seven quarters. On the other hand, change in inflation rate caused increase in unemployment rates up to 0.25% after two years and then their decrease to the original level after next, say, 4 years.

Chart 5. Impulse response functions for Australia



Source: own calculations

Finally, we chose Australia for the analysis, where the rising *CPI* was associated with an decrease of *rGDP* in the second quarter. The rising *HUNR* caused only initially decreases in *rGDP* and in *CPI*.

FINAL REMARKS

In the paper we paid special attention to the analysis of the causal dependencies between the analysed variables and the respective impulse response functions. According to the received results we classified the analysed countries into a number of more or less similar "strategic" groups. It is very difficult, however, to identify factors being the reasons of similar behaviour of all the economies classified to the given group. To this end in future we plan to investigate the same relationships for the same group of countries using the stationary data after splitting the countries into groups with stationarity and trend-stationarity of data as well as with stationarity of their increases.

With this respect we are going to look for analysed relationships for these countries in different phases of the business cycles. Moreover, we plan to extend our analysis substituting CPI by the respective harmonised indices (HCPI).

Finally, on the basis of VAR models we plan to find an empirical long term equilibrium point for each country, just as in case of the three-equational B models. These points will be compared, on one hand, between the countries (using the concept of "strategic" groups maps), and on the other, with results of the analysis of the simultaneous relationships. The results of these comparisons will, we hope, allow for formulation of recommendations for economic policymakers of the respective countries.

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