Testing the Effectiveness of Some Macroeconomic Variables in Stimulating Foreign Trade in the Czech Republic, Hungary, Poland and Slovakia

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Abstract

Some concepts of contemporary econometrics depart from the arbitrary division of variables into endogenous and exogenous. In the estimation process of the econometric model or in prediction process, it may be important to test weak or strong exogeneity of variables. In the foreign trade modelling, we often deal with variables between which there may be feedback. Thus, the causality of variables in the classic sense is not always obvious and it should be tested to facilitate the proper specification of foreign trade models. This article is aimed at testing the exogeneity of selected macroeconomic variables used in foreign trade models, based on Visegrád Group countries. Exogeneity tests made in this paper are based on the results of the VEC and VAR models, which enabled to explain dynamic relations between variables in foreign trade. The results of this research can be helpful for determining the structure of actual links between variables, estimation of proper models and forecasting of variable values.

Keywords

Foreign trade, exogeneity, Visegrád Group, Granger causality test, VAR model, VEC model

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INTRODUCTION

The a priori classification of variables as exogenous and endogenous ones may be troublesome in econometric modelling due to the complexity of economic phenomena occurring in the contemporary world and the existence of feedback between economic values. Such "traditional" classifications are claimed to

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be arbitrary, omitting some variables (the Liu critique) or having parameters in multi-equation models dependent on the values of exogenous variables (the Lucas critique) (Maddala, 2006).

Dilemmas appear also at the level of determining the causality of variables. This happens, for example, in the sphere of international trade where causality of variables understood in traditional way is not always obvious. It can be tested to what extent export is a cause of import or to what extent import is a cause of export. Contemporary econometrics, which offers the Granger causality test, faces these dilemmas. The Granger test assumes *a priori* that there is no distinction between exogenous and endogenous variables. When it comes to the properties of the econometric model and the character of variables occurring in it, it is important to distinguish weak exogeneity, strong exogeneity and superexogeneity of variables (Engle, Hendry, Richard, 1983). Weak exogeneity is required for model estimation; strong exogeneity is needed for forecasting and superexogeneity guarantees that model parameters remain unchanged in relation to variables.

Until recently, the modelling of foreign trade was dominated by "traditional" approach compliant with the interpretation of econometrics offered by the Cowles Commission for Research in Economics in the mid-20th century. This approach is based on the assumption that both the causal structure of the model and the division of variables into endogenous and exogenous are determined in advance and do not require testing. This perception of the role of variables is obvious both in classic models of foreign trade and in models proposed in the new theory of foreign trade which is used to explain new trends in the international exchange of goods and services (e.g. intra-industry trade) (Cieślik, 2000).

The dynamics of contemporary economic phenomena and the progressing globalisation cause that the role of some macroeconomic values in mutual cause-effect relations does not need to be always determined strictly. As a result, it may be difficult to keep the assumption that the foreign trade model has a pre-determined cause-effect structure. Thus, it seems that the testing of variable causality in foreign trade models and the testing of their exogeneity is authorised or even necessary.

In the recent decade or so, there have been attempts in the literature to look at the modelling of foreign trade from the perspective of new econometrics. Granger causality of macroeconomic factors in the models of international trade (Liu, Wang, Wei, 2001, Hsiao, Hsiao, 2006; Sharma, Kaur, 2013; Simionescu, 2014) is tested most frequently whereas the exogeneity of variables in such models (especially strong exogeneity and superexogeneity) is examined less often (Strauß 2002, Mehrara, Firouzjaee, 2011).

This article focuses on the examination of weak and strong exogeneity of the most frequent variables in foreign trade models. Exogeneity tests used in this paper are based on the results of the VEC and VAR models, which enabled to explain dynamic relations between variables in foreign trade. The results of this research can be helpful when determining the structure of actual links between variables, estimating proper models and forecasting variable values. Calculations were done separately for data for Poland, Czech Republic, Slovakia and Hungary, so the Visegrád Group countries. These countries were chosen for their similar economic structure, analogous economic potential, comparable social and economic conditions, and similar economic history in at least the last several decades.

Research results included in this article have led to the formulation of methodological conclusions on the structure of models and conclusions on the effectiveness of some macroeconomic instruments in the development of international trade in individual countries.

1 METHODOLOGY

In the traditional approach corresponding to the approach of the Cowles Foundation, the concept of exogeneity was most frequently identified with predeterminedness or strict exogeneity. A predetermined variable is independent of the current and future values of the random component of an econometric equation. But in case of strict exogeneity, the variable in the equation does not depend on current, past and future values of the random component (Charemza, Deadman, 1997). One of the charges brought against this perception of exogeneity is the fact that it is not stated precisely in relation to what the exogeneity of variables should be considered. Another concept of exogeneity was formulated by Engle, Hendry and Richard (1983), who distinguished weak exogeneity, strong exogeneity and superexogeneity. This article covers weak and strong exogeneity of variables.

Variables are weakly exogenous if they carry all the information necessary for the consistent estimation of the parameters of conditional value in relation to these variables. The function of density $\boldsymbol{f}$, which can be presented as a quotient of conditional probability density function of process $\boldsymbol{f_1}$ and marginal probability density of $\boldsymbol{f_2}$ variable process (Osińska, Kośko, Stempińska, 2007), can prove helpful in defining exogeneity in a more formal way:

$$f(Z_t \mid \mathrm{Z}_{\text{t-i}};\Theta) = f_1(Y_t \mid \mathrm{Y}_{\text{t-i}},\mathrm{X}_{\text{t}};\Theta_1)\cdot f_2(X_t \mid \mathrm{Z}_{\text{t-i}};\Theta_2), \tag{1}$$

where:

Θ – parameter vector whereas $\Theta = [\Theta_1; \Theta_2]$,

X_t, Y_t, Z_t – variables.

Variable Z_t is weakly exogenous in relation to function $\Psi = \mathrm{h}(\Theta)$ if:

- Ψ is the function of only parameters Θ_1 ($\Psi = \mathrm{h}(\Theta_1)$), so the model related to conditional density f_1 is sufficient for estimating parameters,
- there are no mixed conditions for both parameters Θ_1, Θ_2 simultaneously, which means that they are variation free.

Z_t variable is strongly exogenous with respect to variable Y_t for the function of parameters Ψ if:

- variable Z_t is weakly exogenous for Ψ,
- Y_{t-1} is not a Granger cause of Z_t (Charemza, Deadman, 1997).

Weak exogeneity is tested in a slightly different way in the vector autoregression model (VAR model) and in the vector error correction model (VEC model).

VAR model can be presented as follows (Osińska, Kośko, Stempińska, 2007):

$$X_t = A_0 D_t + \sum_{i=1}^{s} A_i X_{t-i} + \varepsilon_t, \tag{2}$$

where:

$\boldsymbol{X_t}$ – observation vector of current values of analysed processes,

$\boldsymbol{D_t}$ – vector containing determinist components (e.g. trend, seasonality),

$\boldsymbol{A_i}$ – matrix of autoregressive operators of individual processes,

$\boldsymbol{A_0}$ – parameter matrix with vector D_t, components,

ε_t – vector of residual processes,

k – VAR model rank.

The existence of time series cointegration is justified by the application of VEC model which can be written, in general, in the following way (Johansen, 1995; Kusideł, 2000):

$$\Delta Z_t = \Psi_0 D_t + \sum_{i=1}^{s} \Pi_i \Delta Z_{t-i} - \Pi Z_{t-1} + \zeta_t, \tag{3}$$

where:

Π – long-run multiplier matrix, $\Pi = \sum_{i=1}^{k} A_i - I$,

Π_i – short-run multiplier matrix, $\Pi_i = -\sum_{i=j+1}^{k} A_i$,

$\boldsymbol{A_i}$ – parameter matrices of polynomial delay operator,

$\boldsymbol{D}_t$ – vector containing determinist components (e.g. trend, seasonality),

$\boldsymbol{X}_t$ – observation vector of the values of analysed processes,

Ψ_0 – coefficient matrix with determinist components of vector $\boldsymbol{D}_t$,

ξ_t – white noise.

The testing procedure of weak exogeneity requires the estimation of the boundary process for variable X_t and conditional one for variable Y_t represented respectively by equations (4) and (5) (Osińska, Kośko, Stempińska, 2007).

$$X_t = \sum_{i=1}^{g} c_i Y_{t-i} + \sum_{i=1}^{h} d_i X_{t-i} + \varepsilon_t, \tag{4}$$

$$\beta Y_t + \gamma_0 X_t + \sum_{i=1}^{p} \gamma_i Y_{t-i} + \alpha \hat{\varepsilon}_t = u_t, \tag{5}$$

where:

X_t, Y_t –variables,

α, β, γ_0, γ_i, c_i, d_i –parameters,

ε_t, u_t– random terms.

The testing of weak exogeneity of X_t variable with respect to variable Y_t involves model estimation (4) and calculation of residuals $\hat{\varepsilon}$. These residuals are then put into the model (5) as realisations of a new explanatory variable. Statistical significance of the parameter next to the added "residual variable" is tested in the estimated model (5). There are no grounds for rejecting the zero hypothesis that the parameter α in question is equal to 0, which means that variable X_t is weakly exogenous in relation to variable Y_t.

The testing of weak exogeneity of the distinguished variable is also conducted in two stages in VEC models. Firstly, it is examined if boundary processes for all variables in this equation do not contain the same mechanism of error correction in the short-run equation of VEC model. Thus, the parameter next to the error correction term is subjected to significance testing (Charemza, Deadman, 1997). In the case the error correction term occurs with different delays in the VEC model, the total significance test F can be conducted for coefficients standing with lagged variables in the error correction mechanism. When there are no grounds for rejecting the zero hypothesis of the insignificance of error correction term, it is omitted in the relevant VEC model equation and the equation is subject to estimation in this form. The further procedure of exogeneity testing is similar as in the case of VAR model. Residuals from the equation with the removed error correction term are put into a different equation of VEC model as new variables. After estimating the second equation, the parameter next to "residual variable" is tested. The Granger causality test is an extra element of the examination of strong exogeneity of variables.

In this test, the causality of variable X (Y) in relation to variable Y (X) occurs when the total influence of the current and delayed explanatory variable X (Y) on Y (X) is statistically significant. According to the tested zero hypothesis, parameters next to the explanatory variable and its delays are equal to zero in confrontation with the alternative hypothesis which states that these parameters are significantly different from zero. Test statistics take the following form (Osińska, 2007):

$$G = \frac{(S^2(u_t) - S^2(\eta_t))/q}{S^2(\eta_t)/(T-m)}\ , \tag{6}$$

where:

$S^2\,(u_t)$ – residual variance in the model without a variable whose causality is tested,

$S^2\,(\eta_t)$ – residual variance in the model with a variable whose causality is tested,

q – number of lags of explanatory variable,

T – size of the sample,

m – number of parameters in the model with an explanatory variable.

Statistics G with the correct zero hypothesis have the Fisher-Snedecor distribution with q and $T\text{-}m$ degrees of freedom, respectively.

The rejection of zero hypothesis proves that the explanatory variable is a Granger cause of the explained variable.

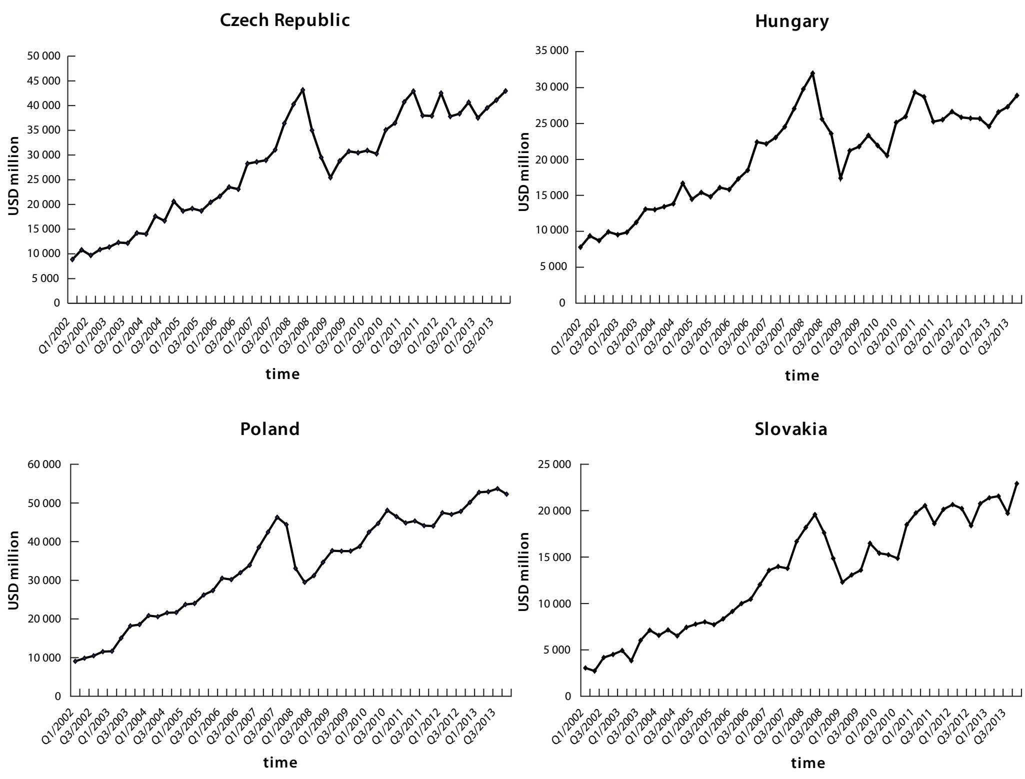
Weak exogeneity of the distinguished variable occurs when in consequence of the conducted test there are no grounds for rejecting the zero hypothesis according to which the parameter of residual variable is insignificant. Strong exogeneity of variables is a reason to use dynamic inference with an estimated model.

2 RESULTS AND DISCUSSION

2.1 Results of stationarity and cointegration test

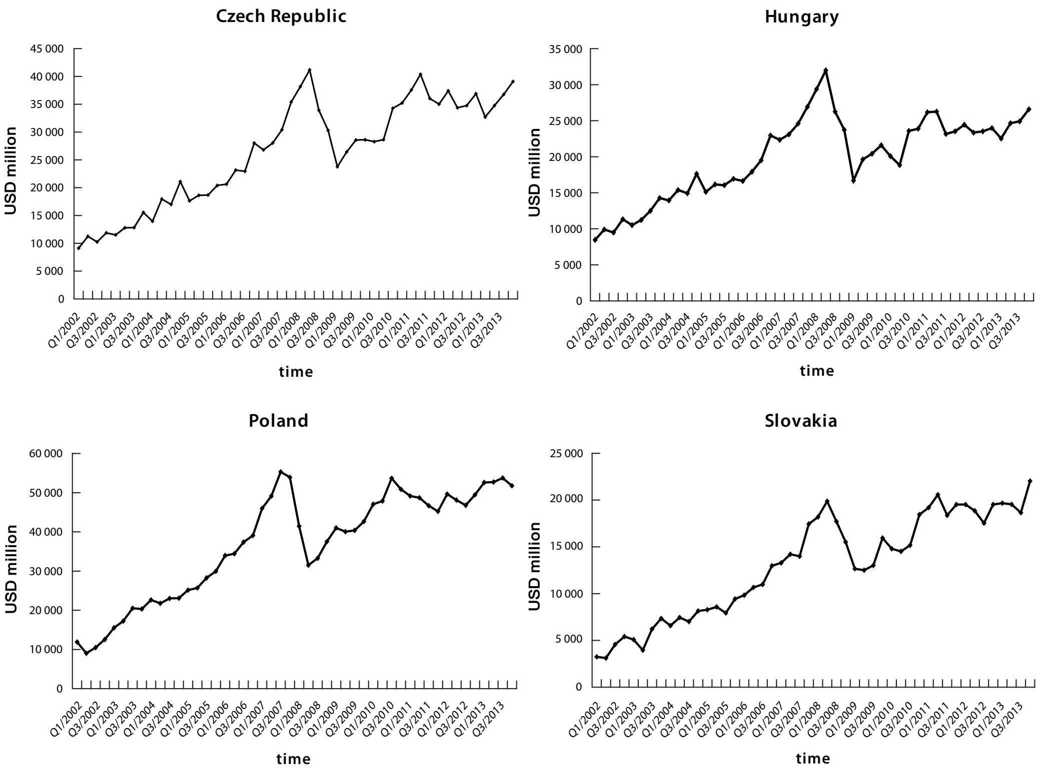
Exogeneity testing considers variables used most frequently in foreign trade models, so export (Ex), import (Im), gross domestic product (GDP), foreign direct investment inflow (FDI), exchange rate (FX). Figure 1 presents time series of export and Figure 2 presents time series of import in Visegrád Group countries. As both figures show, in all countries, the long-term levels of exports and imports are generally increased, although the growth rates are different in each country. We can observe also seasonal and random fluctuations of exports and imports, and the amplitude of fluctuations depends on the period of observation. The strongest export and import fluctuations we can see in Slovakia in 2002–2004, and in Hungary, Czech Republic in 2007–2009.

Figure 1 Export in Visegrád Group countries



Source: Own construction based on data from CEIC database

Figure 2 Import in Visegrád Group countries



Source: Own construction based on data from CEIC database

It is worth noting that the relationships between exports, imports and GDP have been studied in the traditional models of foreign trade. As an example we can mention the gravity model of foreign trade. According to this model the trade flow between countries grows in proportion to the GDP of these countries, and inversely proportional to the square of the distance between them. According to economic theory (Kojima, 1975; Ozawa, 1992) foreign direct investment can enhance export or weaken it. Relations between FDI and exports in economic Ozawa's theory are determined according to the level of economic development of the country. The exchange rate, in turn, affects the competitiveness of exports primarily in short term. As we know, an appreciation of domestic currency can cause the growth of a country's exports. In this research, the domestic currency exchange rate expressed in USD was taken into account. The calculations used data of the Visegrád Group countries from the integrated macroeconomic database CEIC[2] (*A Euromoney Institutional Investor Company)*. The analysis covered time series of variables for the period from Q1 2002 to Q4 2013.[3] VAR or VEC models were treated as a basis for testing the relation between these variables.

[2] <http://www.ceicdata.com>, retrieved: 10/10/2014. CEIC database is a collection of data from, e.g. national statistical offices, central banks, Eurostat, the International Monetary Fund.

[3] Restriction to data for 2002–2013 was caused by the availability of complete quarterly data. Export, import, GDP and FDI values are expressed in USD million.

The choice between these models depended on the results of stationarity and cointegration testsof time series representing individual variables.

The augmented Dickey-Fuller test (ADF test) was used to examine the stationarity of time series (Osińska, Kośko, Stempińska, 2007). The results of the test are presented in Table 1 (*p*-values are given in brackets). The ADF test verifies the null hypothesis, which states that the time series is stationary. Based on the results included in Table 1, it can be stated that time series of original variables were not stationary (with the probability values higher than 0.05) except for FDI time series in Poland and in Slovakia. The first difference of these variables are stationary in all cases. Thus, time series of tested variables are integrated of order 1, except for the two situations mentioned. An optimal variables lag in models is determined according to the Akaike information criterion (AIC) and the Schwarz criterion (BIC). The cointegration of suitable time series was examined and the number of cointegrating vectors was determined with the use of the Johansen test (Johansen, 1991). Table 2 presents the results of information criteria and the Johansen test with the recommendation of the model used to examine the dependence of all pairs of variables in which export is one of the variables. Based on the results in Table 2, it can be stated that only in the Czech Republic the occurrence of a cointegrating vector was detected for each pair of variables, so the VEC model was estimated for these variables. In other countries, the lack of cointegrating vectors was stated for at least one pair of variables and in these situations it entailed the need to estimate the VAR model.

Below is an example of the VEC model built for the import and export of the Czech Republic. Based on the results of a preliminary analysis of dynamic structure of exports and imports time series there is introduced a deterministic linear trend with time variable t and seasonal effects S_i to the VEC model, so $D_t = [S_1, S_2, S_3, t, const]$ i $X_t = [Ex, Im]$. EC1 means the error correction mechanism representing the short-term adjustments process to long-term equilibrium. In brackets, below the parameter estimates, are *p*-values.

$$\Delta Ex = \underset{(0.550)}{-603.57} + \underset{(0.012)}{2.15}\,\Delta Ex\_d - \underset{(0.023)}{2.00}\,\Delta \mathrm{Im}\_d - \underset{(0.007)}{2241.58}\,S_1 - \underset{(0.266)}{2013.69}\,S_2 - \underset{(0.446)}{918.30}\,S_3 + \underset{(0.009)}{335.60}\,t - \underset{(0.014)}{2.16}\,EC1 \tag{7}$$

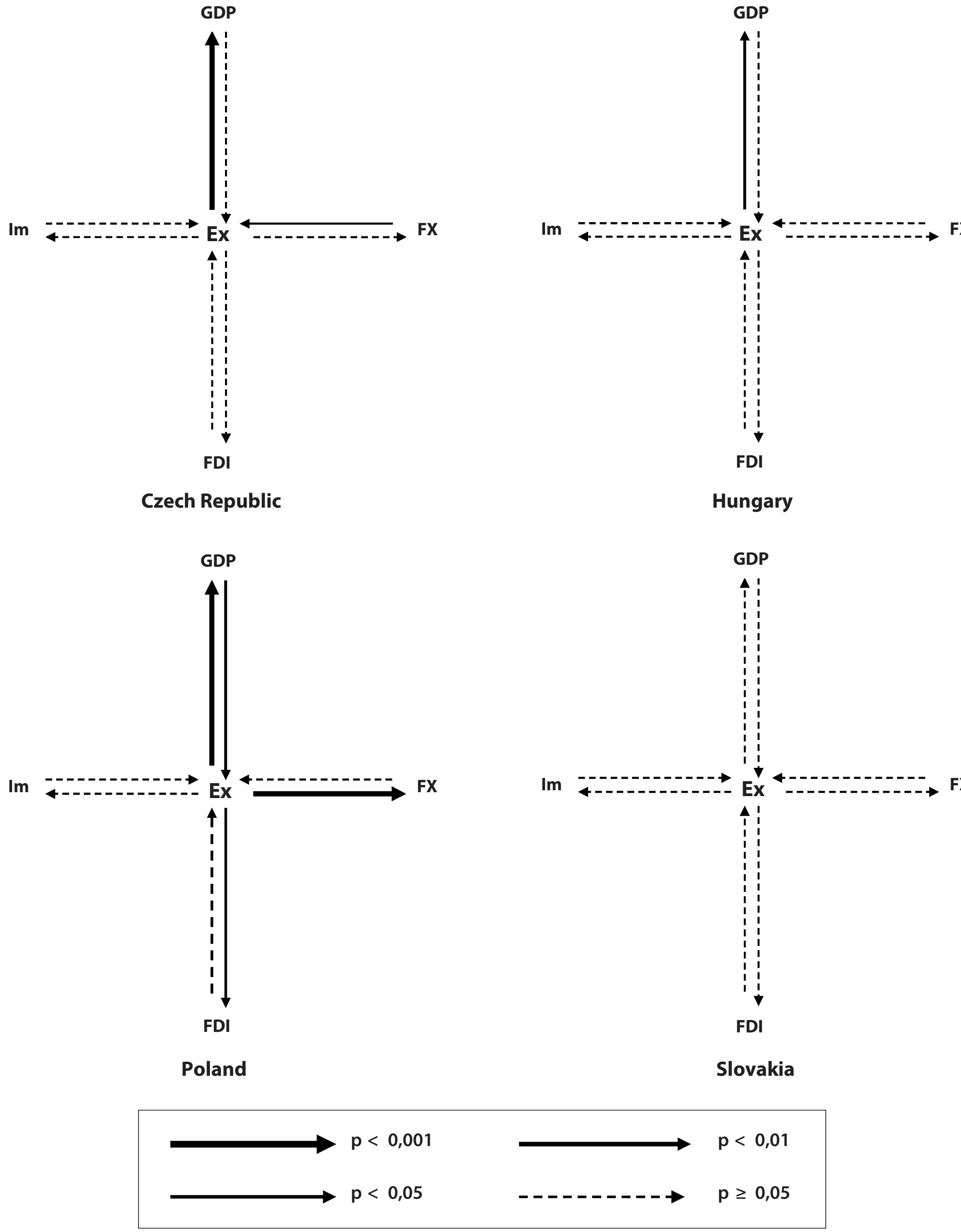
$$\Delta \mathrm{Im} = \underset{(0.769)}{-285.44} + \underset{(0.020)}{1.90}\,\Delta Ex\_d - \underset{(0.038)}{1.76}\,\Delta \mathrm{Im}\_d - \underset{(0.003)}{3663.09}\,S_1 - \underset{(0.308)}{1779.23}\,S_2 - \underset{(0.369)}{1032.25}\,S_3 + \underset{(0.042)}{244.79}\,t - \underset{(0.027)}{1.61}\,EC1 \tag{8}$$

It should be noted that Ex and Im in the previous period, the seasonal component S_1, the time variable t and the indicator EC1 statistically significantly affect the current difference of Ex and Im. Based on the model, we can conclude that an increase of imports in previous period caused a decline of exports and imports in the current period. Similarly, an increase of imports in the previous period causes an increase of exports and imports in the current period. The coefficient of error correction component EC1 is negative in the equations (7), (8), which ensures that a balance through a short-term adjustment process will be achieved. Similarly, VECM and VAR models (as shown in Table 2) were built for other variables and for all countries of the Visegrád Group. On the basis of these models anexogenous or endogenous nature of the variables was identified.

2.2 Results of weak and strong exogeneity test

The confirmation of weak exogeneity of a variable in the macromodel may suggest that it is an effective instrument to influence the foreign trade policy in a given country. The lack of weak exogeneity of a variable means that it is an endogenous part of the equation and it should be modelled in a separate equation. Such a variable is not an effective tool of foreign trade policy and inference based on this variable may be erroneous (Kireyev, 2001). The variable is said to be strongly exogenous if historical changes in the foreign trade structure do not affect the present effectiveness of this variable in the development of international trade.

Figure 3 Granger causal relations for variables used in the modelling of international trade



Source: Author's study

Tables 3 and 4 present the results of testing weak exogeneity of variables, in VAR and VEC models, respectively, in accordance with the procedure described in point 2. Symbol X→Y visible in these tables means the exogeneity of variable X with respect to variable Y whereas in each case export is one of these variables. Based on Table 3, it can be stated that almost all variables in VAR models were weakly exogenous. Export in Poland was an exception as it was not weakly exogenous in relation to import. In VEC models (Table 4) in turn, none of the variables was weakly exogenous, with the exception of the Czech export which was weakly exogenous in relation to GDP.

The Granger causality test was necessary for testing strong exogeneity. The results of the test are illustrated in Figure 3. This figure demonstrates the power of directional dependencies between the analysed variables in individual Visegrád Group countries.

Based on Figure 3, it can be said that the majority of Granger causal relations, including one feedback and two unidirectional causalities, occur in the Polish foreign trade. The strongest causalities are in the direction from export to GDP and from export to the exchange rate. In case of Slovakia, no significant Granger causality was confirmed. In the Czech Republic, only one significant causal relation from export to GDP was diagnosed. In Hungary, export was a cause for GDP and exchange rate was a significant cause for export. Considering the results of the weak exogeneity test and the Granger causality test, conclusions can be formulated with regard to strong exogeneity of variables.

The results of strong exogeneity testing are presented in Table 5. Strong mutual exogeneity in this model suggests that the relevant time series create a system in which equations may be used directly to forecast macroeconomic values (this information can be found in the last column in Table 5). Table 5 shows that the majority of strongly exogenous variables may be seen in dynamic macroeconomic relations occurring in the Slovak foreign trade. In the case of Slovakia, time series of variables in three out of four models create the system. In the Hungarian trade, in turn, one system of equations created by mutually strong exogenous variables was found. In Poland and in the Czech Republic, there are only cases of strongly exogenous unidirectional relations.

Among comparable countries, only Poland is characterised by strongly exogeneous import with respect to export, which means that import may be an effective tool for developing export and historical structure of export does not affect the current import. In other Visegrád Group countries, import is not a weakly exogenous variable. This means that it is an endogenous part of the export model and cannot be treated as a determinant of export. Export is not a weakly exogenous variable with respect to import in any of the Visegrád Group countries. Therefore, this variable may not be used directly in the modelling of import.

2.3 Implications of exogeneity testing results for foreign trade of Visegrád Group countries

GDP is a weakly exogenous variable in relation to export in Slovakia only. Thus, only in Slovakia the value of the produced goods and services is a significant determinant of export whereas historical values of export do not affect the current economic development of Slovakia measured with GDP. On the other hand, Slovakian export is a strongly exogenous variable with respect to GDP. This means that the trade structure may be an effective tool to support economic growth in that country and historical values of GDP have no influence on the current trade structure. Slovakia turned out to be the only country in which GDP and export form the system – it is possible to forecast the values of both variables directly from equations estimated in the VAR model. In each of the other Visegrád Group countries, export was an endogenous component of the model describing GDP and it should be estimated in separate equations. Foreign direct investments can be considered as an effective tool to shape export in Poland, Slovakia and Hungary whereas historical changes of export structure do not affect the current value of FDI in case of Slovakia and Hungary where strong exogeneity of FDI in relation to export was identified. Since export was a strongly exogenous variable with respect to FDI in these countries, the relevant time series of these variables form systems. This opens an opportunity for dynamic inference concerning FDI and export directly from the relevant equations of the VAR model built for Slovakia and Hungary. The export structure in Poland and in the Czech Republic has a considerable impact on FDI but, additionally, in the Czech Republic the earlier structure of FDI does not affect the current export value. Variables represented by time series of foreign exchange rate and export exhibit bidirectional strong exogeneity in case of Slovakia only. This means that the exchange rate is a significant determinant of export and vice versa. But it is also justified to forecast these two values directly from VAR model equations. In the Czech Republic and Hungary, the variables in question have not shown any exogeneity in relation to one another, so they should be modelled in separate equations.

Also exchange rate and export do not form a system in Poland whereas the exchange rate is weakly exogenous with respect to export and export is strongly exogenous in relation to the exchange rate. Therefore, dynamic inference is justified here only on the basis of the VAR model equation which describes the exchange rate.

CONCLUSION

This article presents the contemporary concept of the exogeneity of variables in foreign trade models, based on Visegrád Group countries. The obtained results for strong and weak exogeneity have made it possible to formulate methodological conclusions as well as conclusions concerning the effectiveness of various macroeconomic instruments for the development of foreign trade in individual countries. The presented results allow for analysing macroeconomic variables in the context of the homogeneous estimation of the parameters of VAR and VEC models as well as the possible prediction of the values of variables. On the other hand, conclusions enable the recommendation of foreign trade policy tools, for example, in the context of aiming at balance in foreign trade or deficit reduction in trade.

The presented results lead to the conclusion that in case of Slovakia foreign trade is subject to modelling to a greater extent than in other countries, and this modelling takes into account a dynamic structure of time series of the analysed variables. The presented dependencies also suggest that in case there is no cointegration of time series, strongly exogenous variables occur more frequently than in case when such cointegration exists. In the dependencies described with VEC model, it is much more difficult than in case of VAR models to reject the hypothesis that variables are not strongly exogenous. Obviously, the above conclusion is not universal but it refers to the modelling of foreign trade in specific countries. Potential generalisation of conclusions concerning the exogeneity of variables used in foreign trade models requires further research for the respectively higher number of countries. It is worth noting that this article offers only analyses of weak and strong exogeneity of variables. It seems that the continuation of research on the subject should also lead to testing other kinds of exogeneity, e.g. the superexogeneity of variables. This will enable the verification of additional features of variables, for example in the aspect of the stability of foreign trade model parameters.

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ANNEX

Table 1 The results of the ADF test for variables used in foreign trade models

Variable	Czech Republic		Hungary		Poland		Slovakia	
	primary variable	first difference	primary variable	first difference	primary variable	first difference	primary variable	first difference
Ex	1.146 (0.9328)	–9.060 (0.0000)	0.8532 (0.8912)	–6.572 (0.000)	–1.565 (0.1095)	–9.060 (0.0000)	–0.1544 (0.6251)	–1.0721 (0.0000)
Im	0.9620 (0.9084)	–6.807 (0.0000)	0.6795 (0.8591)	–6.705 (0.000)	–1.729 (0.0793)	–9.113 (0.0000)	–0.0153 (0.4584)	–1.0912 (0.0000)
GDP	0.6253 (0.8479)	–7.190 (0.0000)	–4.134 (0.0001)	–8.494 (0.000)	0.7279 (0.8687)	–7.560 (0.0000)	0.0166 (0.9872)	–0.5054 (0.0001)
FDI	-0.8265 (0.3526)	–5.413 (0.0000)	0.2716 (0.7605)	–10.63 (0.000)	–2.784 (0.0064)	–10.180 (0.0000)	–0.1244 (0.0344)	–1.0365 (0.0000)
FX	0.4672 (0.8119)	–6.819 (0.0000)	–0.9176 (0.3138)	–7.449 (0.000)	0.1942 (0.7382)	–4.508 (0.0000)	0.0077 (0.8620)	–0.9317 (0.0000)

Source: Own calculations based on data from CEIC database

Table 2 The results for Akaike and Schwarz criteria and the Johansen test for variables used in foreign trade models

Variables	Czech Republic			Hungary		
	Optimal order of lag (AIC, BIC)	Number of cointegrating vectors (Johansen test)	Model	Optimal order of lag (AIC, BIC)	Number of cointegrating vectors (Johansen test)	Model
Ex, Im	2	1	VEC	3	1	VEC
Ex, GDP	4	1	VEC	3	1	VEC
Ex, FDI	4	1	VEC	1	0	VAR
Ex , FX	1	1	VEC	1	1	VEC

Variables	Poland			Slovakia		
	Optimal order of lag (AIC, BIC)	Number of cointegrating vectors (Johansen test)	Model	Optimal order of lag (AIC, BIC)	Number of cointegrating vectors (Johansen test)	Model
Ex, Im	5	0	VAR	1	1	VEC
Ex, GDP	5	1	VEC	1	0	VAR
Ex, FDI	5	0	VAR	1	0	VAR
Ex , FX	5	0	VAR	5	0	VAR

Source: Own calculations based on data from CEIC database

Table 3 The results of testing weak exogeneity of variables in VAR models

Country	Variables	The result of test *t* for a residual variable	*p*-value	Weak exogeneity
Hungary	FDI→Ex	–1.126	0.2665	YES
	Ex →FDI	0.5044	0.6166	YES
Poland	Im→Ex	–1.843	0.0741	YES
	Ex→Im	5.721	0.000	NO
	FDI→Ex	–1.390	0.1735	YES
	Ex→FDI	0.6776	0.5026	YES
	FX→Ex	0.7447	0.4616	YES
	Ex→FX	1.577	0.1240	YES
Slovakia	GDP→Ex	0.0799	0.9367	YES
	Ex→GDP	1.183	0.2433	YES
	FDI→Ex	0.2183	0.8282	YES
	Ex→FDI	0.3910	0.6978	YES
	FX→Ex	–0.2958	0.7692	YES
	Ex→FX	–0.5054	0.6166	YES

Source: Own calculations based on data from CEIC database

Table 4 The results of testing weak exogeneity of variables in VEC models

Country	Variables	The test result for lagged variables of error correction term		The result of test t for a residual variable[4]		Weak exogeneity
		F	*p*-value	*t*	*p*-value	
Czech Republic	Im→Ex	0.522	0.597	19.950	0.000	NO
	Ex→Im	3.346	0.045	----	----	NO
	GDP→Ex	3.812	0.011	----	----	NO
	Ex→GDP	1.046	0.398	12.190	0.000	YES
	FDI→Ex	9.792	0.000	----	----	NO
	Ex→FDI	0.327	0.858	1.500	0.143	NO
	FX→Ex	0.921	0.343	9.978	0.000	NO
	Ex→FX	0.533	0.469	9.978	0.000	NO
Hungary	Im→Ex	0.959	0.422	32.060	0.000	NO
	Ex→Im	0.549	0.652	32.000	0.000	NO
	GDP→Ex	19.784	0.000	----	----	NO
	Ex→GDP	0.967	0.419	2.338	0.025	NO
	FX→Ex	3.385	0.073	–2.134	0.039	NO
	Ex→FX	2.000	0.164	–8.688	0.000	NO
Poland	GDP→Ex	1.412	0.247	3.085	0.004	NO
	Ex →GDP	232.479	0.000	----	----	NO
Slovakia	Im→Ex	0.100	0.753	36.710	0.000	NO
	Ex→Im	0.135	0.715	36.520	0.000	NO

Source: Own calculations based on data from CEIC database

[4] A significant result of test *F* for delayed variables of error correction component in VEC models automatically implied the lack of weak exogeneity and the resulting lack of strong exogeneity of a variable. In such situations, *t* test was abandoned.

Table 5 Results of strong exogeneity testing of variables

Country	Variables	Strong exogeneity	System
Czech Republic	Ex→Im	NO	NO
	Im→Ex	NO	
	Ex→GDP	NO	NO
	GDP→Ex	NO	
	Ex→FDI	YES	NO
	FDI→Ex	NO	
	Ex→FX	NO	NO
	FX→Ex	NO	
Hungary	Ex→Im	NO	NO
	Im→Ex	NO	
	Ex→GDP	NO	NO
	GDP→Ex	NO	
	Ex→FDI	YES	YES
	FDI→Ex	YES	
	Ex→FX	NO	NO
	FX→Ex	NO	
Poland	Ex→Im	NO	NO
	Im→Ex	YES	
	Ex→GDP	NO	NO
	GDP→Ex	NO	
	EX→FDI	NO	NO
	FDI→Ex	NO	
	Ex→FX	YES	NO
	FX→Ex	NO	
Slovakia	Ex→Im	NO	NO
	Im→Ex	NO	
	Ex→GDP	YES	YES
	GDP→Ex	YES	
	Ex→FDI	YES	YES
	FDI→Ex	YES	
	Ex→FX	YES	YES
	FX→Ex	YES	

Source: Own calculations based on data from CEIC database