The effects of fiscal policy on output in a structural VEC model framework: The case of four EMU and four non-EMU OECD countries

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Abstract

This paper estimates the effects of government spending and taxation shock on the GDP in the three- and five-variable framework of strucutral Vector Error Correction (VEC) model. The identification of shocks is acchieved by distinguishing between permanent and transitory shocks and by assuming decision lags when implementing fiscal policy. The paper uses recent developments in bootstrap methods to estimate confidence bounds in the impulse response and procedures for insignificant parameters exclusion algorithms to increase the 'precision' of VEC models. The results show that a positive government spending shock increases GDP, while a positive tax shock has a rather insignificant effect on the GDP.

1 Introduction

This paper estimates the effects of fiscal policy shocks on the economic activity i.e. on GDP for which we use a structural VEC (vector error correction) approach, or to say it differently, the method used is a structural VAR approach which takes into account the cointegration between the variables of interest and differentiates between permanent and transitory shocks to identify structural shocks. The four EMU countries in the sample are Austria, Finland, Germany and Italy while the four non-EMU countries are US, Great Britain, Australia and Canada.

It is very important to understand the effects of fiscal policy on the economy simply for the reason that we want to know whether a boost in government spending which we typically understand as expansive fiscal policy shock (keeping government revenues fixed) or boost in taxes (keeping government spending fixed) which we understand as restrictive fiscal policy shock has any effects on the economy and if therefore

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fiscal policy can be seen as a tool to prevent or to dumpen cyclical behaviour of output or prevent recessions. As for this, the real business cycle theory (RBC) claims that a positive fiscal spending shock increases the output (provided that taxes are lump-sum) because there is a negative wealth effect on the individuals (since taxes also must go up by PDV of government spending) so individuals are actually poorer. Therefore they substitute away from leisure to work which raises the output[1] (Baxter and King (1993)). When taxes are distortionary the response of output in RBC world is not clear since it crucialy depends on what is the temporal profile of taxation and how a increase in government spending is financed (i.e. whether we speak of a balanced budget shock or of a deficit financed government spending shock). On the other hand the Keynesian theory suggests that a positive fiscal spending shock increases output through the effect of the Keynes' multiplier.

On the side of empirical work the standard workhorse empirical approach to tackle the effect of fiscal policy on the economy is a structural VAR approach and this papers' main references of the fiscal shock effects on output (Perotti (2002) paper and Mountford and Uhlig (2002) paper) predict that a positive spending shock (deficit financed i.e. leaving taxes unchanged) has a positive effect on output while a positive tax shock (leaving government spending unaffected) has a negative effect on output. Of course there have been many more studies done on the effects of fiscal spending shocks (they are listed in the next section) but the two mentioned empirical studies use two different approaches on how to identify the structural fiscal shocks and their identification, like ours, does not rely on event study approach.

There does not exist a study on effects of fiscal policy which would take into effect the cointegration properties and would distinguish between a permanent and transitory shock when estimating the effects of fiscal policy shocks on the economy. Therefore, both of the two referenced studies (and also others) are misspecified if estimated in first differences (to account for non-stationarity of the series included) since the error correction term is missing (of course provided that government variables and variables of economic activity cointegrate). In addition, the measurement of fiscal policy effects on output may be impeded by a simultaneity problem since if the variations in government spending and taxation are driven by variations in output movements, this evidently affects fiscal policy decisions. Hence, the issue to be solved consists of separating endogenous policy responses from exogenous policy shocks as noticed by Perotti and Blanchard (2002) and by Mountford and Uhlig (2002). The former use institutional information to resolve the issue and the latter the sign restrictions and ordering of shocks. In this paper a structural vector error correction (sVEC) model is used to resolve this problem.

The sVEC framework is closely related to the sVAR (structural Vector Autoregressive) modeling approach since both can be characterized as 'data-oriented'. A characteristic of the structural VAR approach often cited by its critics is an exclusive focus on unsystematic policy shocks, instead of systematic policy. By contrast a structural VEC model is suitable for analyses of the systematic component of fiscal policy if one ore more cointegration vectors can be identified in terms of a fiscal policy rule.

The second advantage of the sVEC framework over the sVAR method is in dealing with unit roots,

[1]This basic insight on the wealth effect does not change if taxes are not lump-sum, however there are three other effects added (intertemporal substitution effect of taxation on consumption and on labour supply and intratemporal substitution effect of taxation) which may lead to a decrease in output in the end, depending on the persistence of the government spending shock and of the government debt process - Baxter and King (1993) give detailed exposition on this.

since there is no agreement in the literature on how to handle unit roots within the sVAR framework. Usually researchers differentiate variables once and estimate the VAR in first differences. Since the general VAR model allows consistent parameter estimation irrespective of whether the time series are I(1) or I(0), very often sVAR models are estimated for the non-stationary levels of the time series, i.e. without consideration of their (co)integration properties, which is questionable if variables are not stationary and not of the same order of integration. For example, Bagliano and Favero (1998), Mountford and Uhlig (2002) use the levels specification since they do not want to restrict the system's long-run behavior by imposing cointegration restrictions. One argument in favor of unrestricted estimation in levels or first differences is that if two or more cointegration vectors are found these are not identified *a priori*, therefore additional identification problem has to be addressed. However, as Phillips (1998) demonstrates, impulse responses for long-run horizons are not consistently estimated in the sVAR with variables specified in levels in the case of unit roots (see also Benkwitz et al., 2001). Phillips (1998) also shows that the VEC specification with consistently estimated cointegration rank significantly improves estimated impulse responses even for short horizons compared to the unrestricted VAR specification. In addition, Abadir et al. (1999) find that the bias of estimated VAR parameters is asymptotically proportional to the sum of the system's characteristic roots. Hence, modeling the system with the cointegration restrictions imposed reduces the bias.

Another benefit of the sVEC approach is that the cointegration restrictions imply a decomposition of the model's innovations into common trend components which have permanent effects on the levels of the variables and components which have only transitory effects. This information can be exploited for the identification of structural permanent and transitory shocks and the simultaneous relationships. Therefore no disaggregated data is needed in contrast to identification technique used by Perotti (2002). In general, additional restrictions have to be introduced to exactly identify the fiscal policy shock, which are very straight-forward in the case of fiscal policy since we are dealing with quite intutitive decision lags in the decision on fiscal spending and taxation process i.e. these decisions have to be granted by a legislative procedure, which usually takes some time. It should be emphasized that changing the model, e.g. by including additional variables, or the assumptions that identify the fiscal policy shock, will likely result in different estimated reactions of the endogenous variables, since the system has to include *all* relevant variables, especially the inclusion of financial variables as conjectured already by Sims (1988). It should be noticed, that the calculated impulse responses *per se* do not reveal information hidden in the data in addition to that implicit in the assumptions introduced to derive them. They can rather be seen only as a tool to summarize the dynamics of a specific empirical model that is based on specific assumptions.

The conclusions of this paper are consistent with that of Perotti (2002) or Mountford and Uhlig (2002) and state that a positive government spending shock has a positive effect and a positive tax shock a negative effect on output in the specification with government spending, taxes and output included. The response to a government spending shock is robust with respect to inclusion of financial variables like inflation rate and interest rate while the tax shock appears to become insignificant for most of the countries in the sample considered.

Framework for the impulse response analysis in this paper will be:

- test for unit-roots of the five variables (government spending, government revenues, output, interest rate and inflation) included,

- determine the cointegration rank and identify cointegration relations using Johansen's (1995) Maximum Likelyhood (ML) and Saikkonen and Lütkepohl (2000) method,

- impose exactly identifying restrictions to compute the contemporaneous and the long-run impact matrix by solving the nonlinear equation system,

- compute the bootstrapped confidence bands of the impulse response funtions (IRF) and report the impulse responses.

The paper is organised in the following way: In section 2 existing VAR studies on the effects of fiscal policy in a VAR framework are shown, in section 3 theory on structural VEC model is presented, in section 4 theory of fiscal rules is shown, section 5 estimates the VEC model and section 6 discusses the structural restrictions used, in section 7 resulting impulse responses are presented and section 8 concludes.

2 Empirical research done on effects of fiscal policy

As Favero (2002, 1) noticed, there is plenty of empirical evidence on the behaviour of monetary policy authorities and its macroeconomic effects but there is only some evidence of the behaviour of fiscal authorities and its macroeconomic effects. Note that for the purpose of this the relevant papers are VAR studies of fiscal policy shocks i.e. those estimating the effects of fiscal policy on the economy because they serve as a reference to determine which are the relevant variables in the system. Studies on fiscal policy shocks will be binding since monetary policy VARs either use monthly data, which is not available for the fiscal policy variables, or they do not use fiscal variables in the sVAR, while as shown below, VARs of fiscal policy shocks include also monetary variables (e.g. Mountford and Uhlig (2002) and Perotti (2002)). For our purposes we need both fiscal and financial variables in the VAR since we want to make explicit distinction between fiscal and monetary shocks. Appealing surveys of fiscal policy VAR studies is in Perotti (2002) and in Favero (2002). Both distinguish between the studies according to the identification approaches. Basically there are four approaches to identify fiscal policy shocks. In turn, the description of each approach is given.

The "narrative" event study approach used in Burnside, Eichenbaum and Fisher (2001) and of Edelberg, Eichenbaum and Fisher (1999) trace the effects of a dummy variable which captures an episode of a sharp fiscal increase like e.g. Korean war military build-up in US, analysed in Ramey and Shapiro (1998). This approach does not help us for our purposes with the identification puzzle since they did it only for the US and without financial variables included, but it is useful for checking whether the shocks identified match the episodes of actual unexpected movement (of course if we have an idea of when they happened).

The second approach is the sign restriction approach by Mountford and Uhlig (2002), which identifies "revenue", "deficit" and "balanced budget" shocks by using sign restriction approach i.e. by imposing that the spending or expenditure side or both move in a certain direction for e.g. four periods in a row. This approach is appealing since one can impose that the fiscal shock should be unanticipated so that the consumption should not respond at the time of the shock, which is a shortcoming of all other fiscal shocks identification approaches. For example, as Mountford and Uhlig (2002) note, there is a specific, non-standard problem in VAR modelling of fiscal policy, which is that fiscal policy surprises do not necessarily coincide with shocks identified in the VAR . But also this approach has drawbacks, main one being that it cannot pin-down exactly when the fiscal policy shock occurs and it is not immune to the a priori views of what a fiscal shock is. Evaluation of the sign restriction approach to the identification is discussed in detail in Perotti (2002, 9).

The third approach by Fatas and Mihov (2001) and by Favero (2002) relies on Cholesky ordering to identify fiscal policy shocks. Fatas and Mihov (2001) order fiscal policy variables first, while Favero (2002) orders fiscal policy variables last i.e. they can not affect prices and output contemporaneously. The drawback of this approach is that a Cholesky decomposition where fiscal policy variables are ordered first would recover a linear combination of automatic response of taxes and government spending to output and price movements, of discretionary response of taxes and government spending to output and price movements and of fiscal policy shocks . On the other hand, if we order fiscal policy variables last, we assume that within a quarter (since monthly data in fiscal policy is virtually non-existent) fiscal policy shocks do not influence output and price movements which is also a questionable assumption.

The fourth approach to the identification is the approach developed by Blanchard and Perotti (2002) who used a 3-variable sVAR and extended in Perotti (2002) when he included additionally financial variables like interest rates and prices. To identify fiscal shocks, they exploit decision lags in fiscal policy and institutional information about the elasticity of fiscal variables to economic activity. With such approach they solve the problem of distinguishing automatic and discretionary responses of government spending and taxes to economic activity and prices from tax and spending shock. This approach allows them to place fiscal variables first since they assume that due to decision lags the government spending does not respond within a quarter to unexpected movements in output, while for the taxation they use independent information from the tax elasticities to output and price movements to construct cyclically adjusted spending and tax residuals. Also this approach has its shortcomings. The main one is the problem of expected or unexpected fiscal shocks, which is reasonable to ask since it is assumed that it takes time for fiscal policy to be implemented (i.e. we have decision lags). However, Blanchard and Perotti (2002) show that for the US taking into account these anticipated fiscal policy does not change the results substantially. Neither do the results change whether the two financial variables are included or not.

Conclusion from all of these approaches is that the problem of the fiscal policy analysis effects is mainly the identification of fiscal policy shocks. All above approaches are characterised by the fact that they require aside some knowledge of the nature of fiscal policy, except for the approach of Mountford and Uhlig (2002) who use an agnostic capproach to identify fiscal policy shocks. Also our approach to identification of fiscal policy shocks will be will be data-driven when identifying the permanent shocks in the system, whereby it will in addition include the correct treatment of the variables which have different integration properties.

3 On structural VEC methodology

Structural VEC (vector error correction) models are an application of the structural VAR methodology to vector error correction (VEC) models with cointegrated variables. The rise of the VAR methodology started with the Sims (1980) and it is very often used tool to perform the impulse response analysis of the identified shocks in the system. The appealing feature of such VAR systems is that they do not treat any of the variables *a priori* exogenous, therefore all of the variables are modelled as endogenous variables and the errors are treated as acutal exogenous variables. Structural VEC analysis starts from a reduced form standard VEC(p) model

$$\Delta y_t = \alpha\beta' y_{t-1} + \Gamma_1 \Delta y_{t-1} + ... + \Gamma_p \Delta y_{t-p} + C^* D_t + u_t \tag{1}$$

where y_t is a $K \times 1$ vector of time series, D_t is a vector of deteministic terms, $\Gamma_1, ..., \Gamma_p$ are $K \times K$ coefficient matrices and C^* is the matrix associated with the deterministic terms in the model, such as a constant, a trend and seasonal dummies. The reduced form disturbance u_t (also called the forecast error) is a $K \times 1$ unobservable zero mean white noise process with covariance matrix Σ_u. For our purposes, the deterministic terms are of no importance because they are not affected by the impulse responses hitting the system and they do not affect such impulses themselves. Therefore, as often in practice, the term will be dropped from this presentation of sVEC model. We are interested on the effects of fundamental shocks on the system variables y_t. They are expressed as

$$u_t = A\epsilon_t \tag{2}$$

where $K \times 1$ vector ϵ_t contains the unobservable structural disturbances (in our case among others the fiscal spending and the tax shocks) and has the covariance matrix Σ_ϵ. Thus, to compute the responses to the structural shocks ϵ_t, we have to identify the A matrix i.e. we need to recover K^2 elements of A. By using the assumption that structural shocks are uncorrelated and have unit variances $\Sigma_\epsilon = I_K$ we get

$$\Sigma_u = E\left[u_t u_t \prime\right] = E\left[\epsilon_t \epsilon_t'\right] = A\Sigma_\epsilon A' = AA'. \tag{3}$$

Now the symmetry of Σ_ϵ and the normalization of the structural variances impose $K(K+1)/2$ restrictions on the K^2 parameters of A. Thus, to exactly identify elements of A, one needs to impose additional $K(K-1)/2$ linearly independent restrictions. For this the VEC has to be expressed as a moving average process.

From Johansen's (1995) version of the Granger's representation theorem it follows that the VEC can be represented in the reduced form as the Vector Moving Average (VMA) process

$$y_t = C(1)\sum_{i=1}^{t}(u_i + \Xi D_i) + C_1(L)(u_t + \Xi D_t) + y_0 \tag{4}$$

where y_0 depends on the initial conditions and $C(1)$ is the total impact matrix computed as $C(1) = \beta\perp(\alpha\perp'(I_K - \Sigma_{i=1}^{p-1}\Gamma_i)\beta\perp)^{-1}\alpha\perp'$. $\beta\perp$ and $\alpha\perp$ represent the orthogonal complements of α and β respectively. $C(1)$ has the reduced rank $rk(C(1)) = (K-r)$ if the cointegrating rank of the system is r. From (4) it follows that the long run effects of structural shocks ϵ_t can be rewritten as

$$C(1)A. \tag{5}$$

Now we can impose long run restrictions as implied by the economic theory by setting elements of (5) matrix to zero. Like in common trends literature we speak about permanent and transitory effects of structural shocks. In particular, if the system has r cointegrating relations, only $k = (K - r)$ shocks can have permanent effects, while r shocks have transitory effects. To exactly identify permanent shocks, we need $k(k-1)/2$ additional restrictions (elements of the matrix $C(1)A$ set ot zero), whereby $r(r-1)/2$ restrictions (elements of the matrix A set to zero) identify the transitory shocks. Together, these are a total of $K(K-1)/2$ restrictions and we have just enough restrictions to identify A.

The estimation of structural just-identified VEC model from involves the setup of the likelyhood function with respect to the structural parameters in the A matrix. This estimation of parameters is equivalent to estimating a simultaneous equation model with covariance restrictions. The details on the estimation will be given in Beritung, Brüggemann and Lütkepohl (2004). For our reference, following Brüggemann (2003) the restrictions from (5) can be written in implicit form as

$$Rvec\left[C(1)A\right] = 0 \tag{6}$$

where R is an appropriate restriction matrix. Following Vlaar (2002) these restrictions can be reformulated such that they are linear in the elements of A. These implicit restrictions can be translated into the explicit form and then used in the maximisation procedure of sVEC model. On the other hand, estimates for the free paramters in A are found by maximising the concentrated log-likelyhood function. Since contemporaneous and long-run run restrictions are written linearly, the estimation procedure of the score of the concentrated log-likelyhood function is obtained by Amisano and Giannini (1997) algorithm.

4 Fiscal rules in theory

For the proper specification of cointegration relations in the used VEC model, some theory on fiscal rules is given below. The theory on fiscal policy rules enhances the correct specification of the cointegrating relationships in the VEC system. We are interested in the relationships between the two fiscal policy variables - taxes (T_t) and government spending (G_t) and the output (Y_t).

4.1 Government solvency condition

The statistical model of a simple fiscal policy rule follows the theoretical model of an accounting identity describing the evolution of government debt at constant prices is

$$B_t \equiv (1 + r_t)B_{t-1} + S_t \tag{7}$$

where B_t and S_t indicate the debt and primary surplus includive of seignorage, while r_t is the real interest rate. Assuming that $r_t \geq 0$ in all periods, we can solve the difference equation (7) forwardly to get

$$B_t = \lim_{n\to\infty} E_t\left(\prod_{s=1}^{n}\left(\frac{B_{t+n}}{1+r_{t+s}}\right)\right) + \sum_{s=1}^{\infty} E_t\left(\prod_{j=1}^{s}\frac{1}{1+r_{t+j}}S_{t+s}\right) \tag{8}$$

where E_t is the expectation operator of conditional on information available at time t. When the term

$$\lim_{n\to\infty} E_t\left(\prod_{s=1}^{n}\left(\frac{B_{t+n}}{1+r_{t+s}}\right)\right) = 0 \tag{9}$$

the debt at time t equals to the sum of discounted future surpluses and so the intertemporal government budget constraint is satisfied i.e. the solvency condition is met. By the approach of Wilcox (1989) if we relax the assumption of constant interest rate, we can discount the variables back to period zero and then can rewrite equation (7) as

$$q_t B_t = q_{t-1} B_{t-1} - q_t S_t, \tag{10}$$

where

$$q_t = \prod_{j=0}^{t} \frac{1}{1+r_j} \tag{11}$$

and $q_0 = 0$. Equation (8) then becomes

$$q_t B_t = \lim_{n\to\infty} E_t(q_{t+n} B_{t+n}) + \sum_{s=1}^{\infty} E_t(q_j S_j). \tag{12}$$

Ahmed and Rogers (1995) show that under mild conditions the first term on the right hand side of (12) is zero if and only if the deficit inclusive of interest rate payments is a zero mean stationary process. If taxes (T_t), government expenditures (G_t) and interest rate payments are I(1) variables, the latter condition is satisfied if and only if

$$T_t = G_t + r_t B_{t-1} \tag{13}$$

is a cointegrating relationship[2]. Or, in the case that in the fiscal spending variable repayment of the debt is included, we would expect the cointegrating relationship to be

$$T_t = \beta G_t \tag{14}$$

where β should be positive and statistically significantly different from zero.

4.2 Theory on automatic stabilisation

This passage builds on the workhorse model of Obstfeld and Rogoff (1995). In the countries that we consider, government absorbs a relatively constant share of output becuase of its stabilizing role. Namely, a typical classification would attribute fiscal policy three main tasks: allocative, redistributive, and stabilizing. In this stylized model we focus on stabilizing role of fiscal policy. There are no nominal rigidities; hence the particular monetary regime is irrelevant. In the model without investment welfare is a direct function of the average variance of consumption. Hence, the stabilizing role of fiscal policy can be interpreted as its contribution to reducing the variance of consumption. This can be done in two ways: by borrowing and lending called the "net borrowing" channel of stabilization, or by sharing risk called the "insurance" channel of stabilization. Thge focus of this simple model is on the "net borrowing" channel. In a two period model the utility function is a special case of CRRA utility function

$$U_0 = E_0 \sum_{t=1}^{2} \log c_t. \tag{15}$$

[2] Note that a cointegrating relationship describes the comovement of the variables over a long time.

The disposable income in both periods is $\bar{y}$. Thus, whether individuals are liquidity constrained or not, the expected value of consumption in both periods is $\bar{y}$. Linearization of (15) about $E(c_1)$ and $E(c_2)$ gives the expression

$$U_0 = 2\log\bar{y} - \frac{1}{2\bar{y}^2}\left[\sigma_{c_1}^2 + \sigma_{c_2}^2\right] = 2\log\bar{y} - \frac{1}{\bar{y}^2}\bar{\sigma}_c^2 \tag{16}$$

where $\bar{\sigma}_c^2$ is the average variance of consumption. In the following stabilization will refer to any policy that reduces the average variance of consumption, holding constant the expected disposable income and consumption. Now government is introduced. In each country, the government taxes individuals at a proportional tax rate in each period and spends the amount $\bar{g}$ per period. Taxes are not distortionary. Initially, we will assume that individuals do not have access to the riskless bond or any state-contingent securities. Government taxes its own citizens and has access to a safe bond in period 1. The disposable income of the individuals and the budget constraints of the fiscal authority are, respectively

$$y_{d_t} = y_t(1-\tau_t) \tag{17}$$

$$\tau_1 y_1 = \bar{g} - b_1 \tag{18}$$

$$\tau_2 2\bar{y} = \bar{g} + b_1 \tag{19}$$

To define the insurance and net borrowing channels of fiscal policy, consider the benchmark case of a fiscal authority that has no effect on the riskless bond. Because of this the net borrowing channel defined as trading in the riskless bonds is not operating. Thus, the government has no effect on the variance of consumption, disposable income or wealth; all the fiscal policy does is to reduce the expected value of disposable income in each period from $\bar{y}$ to $\tilde{y}$. Under the benchmark case the expected utility is

$$U_{0,B} = 2\log\tilde{y} - \frac{1}{2\tilde{y}^2}(\sigma_\mu^2 + \sigma_\epsilon^2) \tag{20}$$

where the B denotes the benchmark. Consider two cases: in the first the individuals are liquidity constrained and cannot trade in any contingent security. Private consumption in each period is therefore equal to the disposable income of the private sector. In this case in period 1, after the shock is realised, the government solves

$$\max_{\tau_1,\tau_2,b_1} U = \log c_1 + \log c_2 \tag{21}$$

subject ot the budget constraint in (17). The constraints can be be solved to express the whole problem as a maximisation with respect to b_1 only. This gives

$$b_1 = \frac{\mu+\epsilon}{2}, \tag{22}$$

$$c_1 = c_2 = \tilde{y} + \frac{\mu+\epsilon}{2}. \tag{23}$$

Thus, borrowing and lending by the government decreases the average variance of consumption i.e. it acchieves perfect consumption smoothing although the individuals are liquidity constrained. This will generate an increase in welfare, which is due to the net borrowing effect. If individuals are free to borrow and lend, because the taxes are non-distortionary, it does not matter in which period the taxation occurs, given the present discounted value of government spending and the net borrowing channel of fiscal policy becomes irrelevant. Thus the fiscal regime acchieved perfect disposable income even when individuals were liquidity constrained.

This simple model suggests that there should be a cointegrating relationship between government revenues variable and output variable[3] in the sense of

$$T_t = \beta Y_t \tag{24}$$

however the magnitude of this variable is not clear since the cointegration coefficient is not interpreted as a share but as a long-run elasticity of one variable with respect to the other, provided that the cointegration relationship is identified and that the variables are in logs (Johansen 2002), which our model says nothing about. So, the automatic stabilisation merely states that there must exist a stationary relationship between a government activity variable and output variable which is intuitive since when the output moves over the cycle, the taxes should comove since many tax revenues are specified in the way so as to depend on the level of economic activity (the same idea is used in Perotti (2002) however in a different way).

5 Structural VEC models construction

5.1 Data and countries in the sample

As mentioned in the introduction, in the sample of the countries there are four non-EMU OECD countries namely USA, Great Britain, Canada and Australia and four EMU countries: Germany, Austria, Italy and Finland. The choice of the countries in the analysis was determined mainly by the availability of the data.

In the benchmark specification the VEC model includes the following variables:

- the log of real government spending on goods and services G_t,

- the log of real net primary taxes T_t,

- the log of real output Y_t,

For the robustness check two additional variables will be included in the VEC model:

- the inflation rate π_t and

- the interest rate i_t.

The detailes on the construction of the fiscal variables used in the system for the four non-EMU OECD countries is given in the footnote[4]. The sample period is defined for Australia from 1963q2 to 2001q2,

[3] Or, if we take into account that government has to be solvent in the long-run from previous chapter, between government expenditures variable and economic activity variable.

[4] The two fiscal variables used in the VEC for the four non-EMU OECD countries are defined as in Perotti (2002, 13), so:

Net taxes = Revenues - Transfers

Revenues = Tax revenues (Direct taxes on individuals + Direct taxes on corporation + Social security taxes + Indirect taxes) + Non-tax revenues (Current transfers received by the general government) + Net capital transfers received by the general government (Social security transfers to households + Other transfers to households + Subsidies to firms + Transfers abroad)

Government spending on goods and services = Government consumption for Canada from 1961q1 to 2001q4, for Great Britain from 1963q1 to 2001q2, for USA from 1960q1 to 2001q4, for Germany from 1966q1 to 1998q4, for Italy from 1960q1 to 1998q4, for Austria from 1964q1 to 1998q4 and for Finland from 1970q1 to 1996q4. The periodicity of the data is quarterly for all variables included.

For the EMU countries Germany, Austria, Italy and Finland the source of data was *International Financial Statistics* database of International Monetary fond. The variables are defined as follows. The data on government revenues and expenditures are flows and are on a cash basis. Revenue variable (T_t) comprises all nonpayable government receipts, whether requited or nonrequited, oter than grants. Revenue is shown net of refunds and other adjustment transactions. Expenditure (G_t) comprises all nonrepayable payments by government, whether requited or unrequited and whether for current of capital purposes. Note, that in the analysis has to be taken into account that there is a level shift in the series for Germany in the second quarter of 1990 due to the unification.

The net taxes as well as government spending on goods and services were deflated with the implicit GDP deflator to get T_t and G_t as defined above. To get the log of the real output Y_t the nominal Gross domestic product was taken, deflated with the implicit GDP's deflator. For the the inflation rate π_t the IMF's inflation rate series was taken, while as a rule the central bank interest rate i_t is the three-months bills rate.

For Australia the source of fiscal data is National Income and Product Accounts, Publication No. 5206, by Australian Bureau of Statistics; CANSIM II data base for Canada, the United Kingdom National Accounts and the financial statistics files, from the office of national statistics for the United Kingdom and the NIPA accounts from the Bureau of Economic Analysis for the US. The data is deflated with the implicit GDP deflator. The series T_t, G_t and Y_t are seasonally adjusted with the X11 multiplicative procedure in EViews[5].

Integration of all variables in the analysis is left-out of the paper and is available from the author. Tests show that all the variables used in the analysis are non-stationary, they are integrated of order one. This was tested with the Augmented Dickey Fuller ADF test whereby a trend was included in the test for the series T_t, G_t and Y_t and only constant was included in the series π_t and i_t. Autoregressive lags included in the series when tested for the unit root were taken (mainly) according to the Akaike information and Final prediction error criterion, since ADF test is quite sensible to the number of autoregressive lags included. Note that the two nominal series π_t and i_t as a rule have residual ARCH effects present as well as residuals significantly different from those from a normal distribution[6]. For Germany a Unit Root test with a structural break was used as suggested by Lanne, Lütkepohl and Saikkonen (1999) since it outperforms the ADF test in the case of Germany beacuse of the level shift in 1990.

+ Government gross capital formation (Gross fixed capital formation
by the government + Net acquisition of non-produced non-financial assets + Change in inventories

[5] The procedure was performed using the statistical software EViews 4.1.

[6] For these two effects ARCH-LM test and Jarque Bera test for non-normality were performed.

5.2 Cointegration analysis

Cointegration of variables was carefully examined, since we would like to test empirically how many cointegrating relationships (and therefore stochastic trends) are there and how to identify them. The analysis starts with the three variable VEC with Y_t, T_t and G_t and then continues with π_t and i_t added. The reason behind such a choice is that if we would start straight away with a five variable system, there would be too many candidates for the identified cointegrated relationships which would create confusion (as seen below, in the case of five variable VEC, for three cointegrating vectors there at least five candidate rules, besides the above mentioned two fiscal rules the Fisher relation, the modified Phillips curve and the Taylor rule). Instead, we will expand the 3-variable VEC with the observation that cointegrating relations enjoy the property that if the information set is increased by adding new variables, the cointegration relations found for the smaller information set correspond naturally to cointegrating relations in the larger set where the added variables have a zero coefficient (Johansen 1995, 42).

As for the testing procedure the Johansen trace test was used for all the countries except for Germany for which Saikkonen and Lütkepohl (2000) test for cointegration with a structural break was used. The number of autoregressive lags in the system were chosen so as to comply with the rule-of-the thumb that there should not be less than five observations for every short-run autoregressive parameter estimated in the VEC model whereby the exclusion of insignificant parameters according to the top-down algorithm with respect to the Akaike information criterion was taken into account. For that reason the lag-length of the autoregressive lags was not chosen by any of the available information criteria[7] (see Lütkepohl (1991)) for a list of them).

Results of the cointegration analysis of the benchmark specification when all three variables are included in the VEC model are presented in the Appendix A. Results show that in the benchmark specification $Y_{t,}$ G_t and T_t included the system are driven by one stochastic trend since there appear as a rule for all countries in the sample two cointegrating relationships. The following two systems of cointegrating relationships makes sense (we will write it in terms of equation (1))

$$\begin{bmatrix} \Delta Y_t \\ \Delta T_t \\ \Delta G_t \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \end{bmatrix} \begin{bmatrix} 1 & 0 & \beta_1 \\ 0 & 1 & \beta_2 \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ T_{t-1} \\ G_{t-1} \end{bmatrix} + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + C^* D_t + u_t. \tag{25}$$

where in the equation the vector of variables y_t is defined as $y_t = \begin{bmatrix} Y_t & T_t & G_t \end{bmatrix}'$. Note that the cointegrating relationship between Y_t and G_t instead of the one between Y_t and T_t will be considered since as often assumed budget shocks are driven by expenditure shocks whereas there is no immediate response of revenues. This assumption is not unreasonable if one considers the political economy of budget processing though: government spending is determined first and taxes set accordingly (Beetsma

[7] E.g. Akaike information criterion (AIC) gives wrong inference on the optimal lag length of the model if exclusion of insignificant lags is taken into account. This can be shown analytically if we take the definition for AIC(n)= $\log\det(\frac{1}{T}\Sigma_{t=1}^{T}\hat{u}_t\hat{u}_t) + \frac{2}{T}nK^2$ where n is the number of lags included, K is the number of parameters and $\hat{u}_t$ are fitted residuals. If we suppose that only every second lag has significant parameters, then AIC($2n^*$) will have the same value as the original AIC(n) where n^* is the number of parameters in the VEC mdel with subset restrictions.

and Bovenberg, 1998). We chose the specification as in the equation (25) because the reason that we want to identify both the solvency rule and the automatic stabilisation rule from the section 4 which is possible in this case because the first cointegrating vector gives us the automatic stabilistaion rule and the second vector the government solvency rule[8].

5.3 VEC models in the three-variable case

In this section results on cointegrated models of the eight countries in the sample are presented. All models in the three-variable specification as in the equation (25) are presented with number autoregressive lags (in differences) chosen so that no residual autocorrelation is left in the models. The significance of lags is being tested with the Aikaike information criterion top-down procedure as developed by Brüggemann and Lütkepohl (2001). Top-down is a sequential elimination algorithm implemented in JMulTi i.e. it is a procedure which starts from the last regressor in the equation and checks if deleting it improves the Akaike criterion value. In that case it is eliminated. Otherwise it is maintained. Then the second last regressor is checked and so on.

Dummies are included in cointegrated models whenever there is a sound economic interpretation of them and whenever they help to improve the quality of the VEC model i.e. to make the resulting residuals not significantly different from those of a normal distribution. This is very important since the dummies can be interpreted also as fiscal spending or fiscal revenue shock which decrease the quality of the shocks identified in the next step of the analysis - the structural identification of shocks in the VEC. The trade-off between including them or not, however, exists and there does not appear to be any better way than to find a sound reason for each and every of them included. This we do below in the detailed analysis for every country in the sample.

In the following, the results on the α and β' matrix are presented for each of the eight countries in the sample. In addition the summary statistics of all of the eight benchmark VEC models are presented. The reasons for including different lags for different countries included in the sample is that the information criteria are not very useful as a guidance for autoregressive lags included since they would for many countries suggest to include one or even no lags in differences in the system which is cleraly unsatisfactory from the viewpoint of impulse response analysis.

The significance of the parameters in the β matrix is being tested with the adjusted t-test (critical value with a 95% confidence level is 1.96) and it is found that the parameters in both the solvency and the automatic stabilisation rule under the benchmark specification for all countries are being significant. We will not deal in length with the interpretation and discussion whether the values for the coefficients of both rules are according to the theory. Nevertheless, from the first glance it can be seen that the parameters for the solvency rule are quite near the value of one while those for the automatic stabilisation rule are on a wider range.

The VEC models chosen with time period included, number of lags and dummies included are shown and discussed in the following subsections. The resulting fiscal rules are shown in table 1 below (the two cointegrating relationships in the β matrix). From the loading coefficients we can conclude that the

[8] Note that the specific form with a zero in each row of β matrix is imposed in order to identify the two cointegration vectors.

stochastic trend is output for all countries included since the loadings entries in the α matrix are such that first cointegrating relation does not significantly enter into the Y_t.

5.3.1 Finland

The VEC model was chosen with six lags in differences[9]. The sample taken into account was from the first quarter 1970 to the fourth quarter 1990. The reason is that the government spending and revenues variables are too noisy in the nineties one reason for which could be the preparation of the country to enter into EMU, since Finland experienced sharp rise in government spending raisnig form 36% of GDP in 1975 to 60% of GDP in 1991 and Finland had to change the fiscal policy to stabilize the government debt according to the Maastricht criteria[10]. In addition the impulse dummy was included for taxes in the fourth quarter of 1975. For this dummy inclusion the explanation is that it is the only additive to make the resulting VEC model behave very good (in addition it is highly significant with t-value ot 7.6).

The resulting statistics of the specified VEC are no residual autocorrelation (adjusted Portmonteau test p-value 0.08), no non-normality in the residuals of individual series (Jarque-Bera p-values: 0.06 for u_{Y_t}, 0.56 for u_{T_t} and 0.33 for u_{G_t}) and not residual ARCH (p-values 0.11 for u_{Y_t}, 0.86 for u_{T_t} and 0.83 for u_{G_t}).

5.3.2 Germany

The VEC was chosen with six lags in differences to which the procedure of exclusion of insignificant lags was applied. The sample length is the whole period. The impulse dummies included were the unification dummy in second quarter 1990, the second supply shock dummy in fourth quarter 1978 (t-statistics 5.23) which significantly affects taxes, and the two government spending cuts dummies in second quarter 1982 (t-value 4.67) and in second quarter 1988 (t-statistics 7.83). The resulting model has no residual autocorrelation (augmented Portmonteau p-value is 0.92), no non-normality in the residuals of individual series (Jarque-Bera p-values: 0.38 for u_{Y_t}, 0.45 for u_{T_t} and 0.82 for u_{G_t}) and not residual ARCH (p-values 0.08 for u_{Y_t}, 0.81 for u_{T_t} and 0.32 for u_{G_t}).

5.3.3 Austria

In the VEC specification the sample included will be from first quarter 1964 to last quarter 1996. The last eight quarters will be left out of the analysis because they include too much noise due to fiscal stabilisation program. The autoregressive lags included in the models are five (in differences) with the top-down algorithm applied according to Akaike criterion. The dummies included are for the the second supply shock for output in first quarter of 1978, the government spending outlier in fourth quarter of 1975 (the same as for Finland) and a tax outlier in fourth quarter of 1985. The resulting VEC has the following properties: it has no residual autocorrelation (adjusted Portmonteau p-value of 0.23), slight

[9] For which the top-down algorithm according to Akaike information criterion was performed as for every other country in the sample.

[10] One could expect in the beginning of the nineties a structural break but there is not enough data to split the sample and test this prediction.

non-normality in the residuals of individual series (Jarque-Bera p-values: 0.03 for u_{Y_t}, 0.05 for u_{T_t} and 0.05 for u_{G_t}) and no residual ARCH (p-values 0.28 for u_{Y_t}, 0.99 for u_{T_t} and 0.99 for u_{G_t}).

5.3.4 Italy

VEC model is build on data from first quarter 1970 to fourth quarter 1998. The sixties will be left out of the analysis because they include too much noise. The autoregressive lags included in the models are six (in differences) with the top-down algorithm applied according to Akaike criterion. There are no dummies included in the model, which behaves reasonably well. The resulting VEC has the good properties: it has no residual autocorrelation (adjusted Portmonteau p-value of 0.15), slight non-normality in the residuals of individual series (Jarque-Bera p-values: 0.02 for u_{Y_t}, 0.08 for u_{T_t} and 0.10 for u_{G_t}) and no residual ARCH (p-values 0.58 for u_{Y_t}, 0.94 for u_{T_t} and 0.73 for u_{G_t}).

5.3.5 United States

For US there appears to be a structural break in the fiscal spending and tax rule. This is confirmed by both the sample-split (bootstrapped p-value 0.01) and break-point (bootstrapped p-value 0.00) Chow test[11]. We can distinguish the pre-Reagan and post-Reagan era. There are many indicators showing to this: the Chow tests show that there is likely to be a sample split, there is a big outlier in taxes in the fourth quarter of 1983 and the whole sample model behaves badly in terms of residual autocorrelation.

The sample will be split in the first part from 1960 first quarter to 1982 fourth quarter and in the second part from 1983 first quarter to 2001 fourth quarter. For the first subsample model the VEC will be chosen with six lags in differences with top-down exclusion of insignificant parameters in the VAR, with second supply shock in output dummy in the second quarter 1978 included and the president Johnson's spending increase in first quarter 1967. The resulting VEC has no residual autocorrelation (adjusted Portmonteau p-value is 0.892), no non-normal residuals (Jarque Bera p-values are 0.55 for u_{Y_t}, 0.14 for u_{T_t} and 0.91 for u_{G_t}) and no residual ARCH (p-values 0.99 for u_{Y_t}, 0.04 for u_{T_t} and 0.60 for u_{G_t}).

In the second model for US 5 lags in differences were chosen, no dummies included, subset exclusion of insignificant short-run parameters performed just like for the first period. The resulting model behaves well since the adjusted Portmonteau p-value is 0.16, the Jarque-Bera test p-values are 0.79 for u_{Y_t}, 0.82 for u_{T_t} and 0.44 for u_{G_t} and the residual ARCH p-values are 0.63 for u_{Y_t}, 0.81 for u_{T_t} and 0.85 for u_{G_t}.

5.3.6 Australia

The specification used for Australia is from second quarter 1963 to last quarter 1988. The reason for that is that there was most probably a structural break in fiscal variables in Australia with the beginning of the nineties. The additional support for that is the break-point and sample-split Chow test (bootstrapped p-values 0.01 and 0.00 respectively) which shows the existence of such break. There are 5 AR lags included in the model (insignificant excluded with the top-down algorithm, of course, like for other countries in

[11] Because the actual small sample distributions of the test statistics under may be quite different from the asymptotic ones (Candelon and Lütkepohl 2001). Therefore the p-value was bootstrapped 2000 times. For this the JMulti2.64 software was used where the procedure is described in detail.

the sample). The resulting model has good properties in terms of no residual autocorrelation left in the residuals (adjusted Portmonteau p-value is 0.2234), normality of residuals (Jarque Bera p-value is 0.81 for u_{Y_t}, 0.71 for u_{T_t} and 0.55 for u_{G_t}) and ARCH effect in residuals since univariate ARCH-LM p-value is 0.32 for u_{Y_t}, 0.83 for u_{T_t} and 0.82 for u_{G_t}.

5.3.7 Canada

The VEC model for Canada is a model from first quarter of 1961 to last quarter of 2001. The model includes six autoregressive lags (with top-down algorithm applied to exclude insiginificant ones) and no dummies. The resulting test statistics show no residual autocorrelation (adjusted Portmonteau p-value is 0.63), slightly non-normal residuals in government spending and tax variable (Jarque Bera p-value is 0.59 for u_{Y_t} 0.01 for u_{T_t} and 0.05 for u_{G_t}) and no ARCH effects in residuals (ARCH-LM p-value is 0.09 for u_{Y_t} 0.43 for u_{T_t} and 0.12 for u_{G_t}).

5.3.8 Great Britain

The VEC used was from the first quarter 1963 to the second quarter 2001 with six autoregressive lags included and insignificant short coefficients excluded in the same way like for other countries. In the model no dummies were included. The resulting model has no autocorrelation left in the residuals (adjusted Portmonteau p-value is 0.16), there is slight non-normality in the model (Jarque Bera p-value is 0.02 for u_{Y_t} 0.43 for u_{T_t} and 0.03 for u_{G_t}) and slight ARCH effects in residuals are present (ARCH-LM p-value is 0.01 for u_{Y_t} 0.82 for u_{T_t} and 0.04 for u_{G_t}).

Table 1: Fiscal rules and loading coefficients

	Automatic stabilisation				Solvency			
	α_{Y_t}	α_{T_t}	α_{G_t}	The rule	α_{Y_t}	α_{T_t}	α_{G_t}	The rule
Finland	0.04 (0.96)	0.89 (5.83)	−0.22 (−1.74)	Y_t=0.36G_t (6.2)	−0.02 (−0.62)	−0.53 (−5.42)	0.17 (2.26)	T_t=1.32G_t (13.8)
Germany	0.01 (2.11)	0.22 (3.18)	−0.03 (−3.44)	Y_t=0.88G_t (33.4)	−0.02 (−1.56)	−0.21 (−4.02)	0.18 (3.69)	T_t=1.07G_t (23.7)
Austria	−0.06 (−2.18)	0.00 (1.24)	0.01 (6.35)	Y_t=0.57G_t (12.1)	−0.02 (−1.45)	−0.19 (−2.32)	0.19 (3.38)	T_t=0.96G_t (28.1)
Italy	0.01 (1.39)	0.88 (5.11)	0.07 (3.48)	Y_t=0.27G_t (3.8)	−0.01 (−1.94)	−0.90 (−5.47)	−0.23 (−3.27)	T_t=0.65G_t (5.9)
USA to 1983	−0.01 (−0.77)	0.05 (4.68)	0.04 (3.36)	Y_t=2.67G_t (10.1)	0.24 (3.19)	−0.16 (−4.71)	−0.02 (−0.33)	T_t=1.40G_t (28.7)
USA from 1983	0.02 (1.70)	0.04 (4.18)	0.04 (3.98)	Y_t=1.91G_t (27.8)	−0.03 (−0.40)	−0.15 (−4.23)	0.04 (0.77)	T_t= 0.97 G_t (100.3)
Australia	−0.11 (−2.02)	−0.09 (−1.88)	0.24 (2.89)	Y_t=1.02G_t (16.1)	0.04 (2.42)	−0.02 (−1.66)	−0.04 (−1.73)	T_t=1.53G_t (6.1)
Canada	0.00 (0.16)	0.08 (2.20)	−0.00 (−0.14)	Y_t=1.48G_t (9.4)	0.01 (0.94)	−0.02 (−2.21)	0.01 (1.01)	T_t=2.27G_t (7.6)
Great Britain	−0.00 (−0.40)	0.01 (1.54)	0.03 (1.83)	Y_t=2.77G_t (11.5)	0.00 (0.14)	−0.06 (−1.47)	0.01 (1.16)	T_t=1.27G_t (3.8)

Notes: α_{Y_t}... stands for the loading coefficient of the identified rule into the equation for the variable denoted as a subscript (in our case into the equation for Y_t). In the brackets below the rules the t-statistic is reported.

5.4 Five-variable cointegrated systems

In addition to the three-variable VEC specification, the other specification in this paper is the five variable specification. The reason for the inclusion of two additional variables is the system, namely inflation rate π_t and the interest rate i_t is that the system without these two variables may not capture all relevant information in our system. That because the ϵ_t is all that we have not modelled and they will change if we try to model more, that is, include more variables. In addition, the common trend may change by including additional variables. In this sense the interpretation of a common trend depends on the information set.

The second reason is the so called Sims (1988) conjecture. In the Brookings comparison project small scale econometric models typically displayed larger fiscal multipliers than large scale rational expectation models that included interest rate and prices. Sims (1988) conjectured that these results could be explained by the presence of financial variables,like interest and prices,in the larger scale models; these jump variables embody expectations of future changes in fiscal policy,and absorb some of the estimated effects of fiscal shocks. To test the Sims conjecture, we can estimate a three variable VAR which includes the interest rate and the inflation rate.

The third rationale for including interest rates is that in its absence fiscal shocks might pick up the effects of interest rate shocks if there is some systematic contemporaneous relationship between monetary and fiscal policy.

The cointegration tests for all five variables showed that there are two stochastic trends present in the system because there are three cointegrating relationships present for all countries in the sample[12]. The results are presented in Appendix B. We already have identified two cointegrating relationships as the two fiscal rules, so now the question is to identify the third one. The obvious answer to take is the Fisher relation which combines the nominal interest rates with inflation rate since it is known that the real interest rate should be constant over time.

The resulting VEC model of five variables will thus be in the following form in which we expand the β matrix from VEC form given in (1)

$$\begin{bmatrix} \Delta i_t \\ \Delta T_t \\ \Delta Y_t \\ \Delta \pi_t \\ \Delta G_t \end{bmatrix} = \alpha \begin{bmatrix} 1 & 0 & 0 & \beta_{11} & \beta_{12} \\ 0 & 1 & 0 & \beta_{21} & \beta_{22} \\ 0 & 0 & 1 & \beta_{31} & \beta_{32} \end{bmatrix} \begin{bmatrix} i_{t-1} \\ T_{t-1} \\ Y_{t-1} \\ \pi_{t-1} \\ G_{t-1} \end{bmatrix} + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + C^* D_t + u_t. \tag{26}$$

where we expect the β_{12} coefficient to be zero because obviously taxes do not enter into the Fisher relation[13]. We also expect that the coefficients β_{21} and β_{22} will not be significantly different from zero since there is no reason to believe that the inflation rate enters significantly into a fiscal policy rule. The loadings in the α matrix gave us reference that the second stochastic trend is coming from inflation[14].

[12] Again, for Germany the Saikkonen and Lütkepohl test was performed because of the unification level break.

[13] It would be of interest to see whether a fiscal variable enters into the simple monetary policy rule, but this would clutter the analysis too much.

[14] As we know, the α matrix entries give reference to the loadings of the cointegrating relationships into the variables in the system. The results on loadings are left out because of the space constraint.

This is intuitive since it is hard to justify why a shock in the interest rate should have permanent effects.

When five-variable systems were run the resulting residual autocorrelation statistics are shown in the following table.

Table: Autocorrelation and joint non-normality tests of five variable VEC models

	adjusted Portmonteau p-value	Joint non-normality p-value+
Great Britain	0.09	0.02
Canada	0.71	0.04
Australia	0.06	0.20
USA first half	0.74	0.22
USA second half	0.22	0.02
Italy	0.25	0.00
Germany	0.27	0.09
Finland	0.36	0.01
Austria	0.52	0.02

Notes: + ... Test taken from Lütkepohl (1993), Introduction to Multiple Time Series Analysis, 2ed, p. 153.

6 Structural identification

From section 3 for the 3-variable VEC we need $K(K-1)/2 = 3(3-1)/2 = 3$ linearly independent restrictions to exactly identify the structural shocks. We know from section 5 that because of two cointegration relations only shocks in Y_t can have permanent effects i.e. Y_t is a stochastic trend in the system. So, since we have $r = 2$ (two cointegrating relatins), $k = (K - r) = 1$ shock has permanent effects. We will call it a real trend. Therefore shocks in T_t, G_t can have no permanent effects on any of the variables in the system (two columns restricted to zero in the equation $C(1)A$). This implies two lineraly independent restrictions ($kr = 2$), so additional one restriction has to be made in the short run matrix (since $k(k-1)/2 = 1$). So, we will assume in addition that the tax shock ϵ_{T_t} has no effect on government spending G_t within a quarter (Beetsma and Bovenberg (1998) thesis of residually determined T_t after G_t is set). Since order of the the variables in the following order Y_t, T_t, G_t then the identification of the short run matrix A and the long run matrix $C(1)A$ in the three variable system will be the following:

$$A = \begin{bmatrix} * & * & * \\ * & * & * \\ * & 0 & * \end{bmatrix}, C(1)A = \begin{bmatrix} * & 0 & 0 \\ * & 0 & 0 \\ * & 0 & 0 \end{bmatrix} \tag{27}$$

which can be interpreted as the assumption that government spending and government revenues variable have no long-run effect on GDP and on each other (last two rows in matrix $C(1)A$). This makes sense as shown from the cointegration anaylsis already and it is also intuitive. Since the restrictions from the long-run matrix give us two linearly independent restirctions, we need one more to identify the sVEC. We will do this by setting the effect of a tax shock on government spending within a quarter to zero. This restriction is intuitive, since noticed by Beetsma and Bovenberg (1998) government spending is set and taxes are set residually. This is intuitive since government decision processes have to go through the legislative body and therefore the decision process is very likely to take more than one quarter. In addition in a two variable (G_t, T_t) VEC model for all countries in the sample the stochastic trend comes from government spending variable (results left out for the space reasons).

In the five-variable VEC with the order of variables $i_t, T_t, Y_t, CPI_t, G_t$ the identification will be the following. We need $K(K-1)/2 = 5(4-1)/2 = 10$ linearly independent restrictions. There are $k = (K-r) = 2$ shocks with permanent effects, while $r = 3$ have transitory effects. The short run matrix A and the long run matrix $C(1)A$ will be identified in the following way

$$A = \begin{bmatrix} * & * & * & * & * \\ * & * & * & 0 & * \\ * & * & * & * & * \\ * & * & * & * & * \\ * & 0 & 0 & 0 & * \end{bmatrix}, C(1)A = \begin{bmatrix} * & 0 & * & 0 & 0 \\ * & 0 & * & 0 & 0 \\ * & 0 & * & 0 & 0 \\ * & 0 & * & 0 & 0 \\ * & 0 & * & 0 & 0 \end{bmatrix}. \tag{28}$$

The three colums of zeroes in the matrix of long-run effects are coming from the cointegration analysis and mean that there is no long-run effect of either of the three policy variables (G_t, T_t, i_t) on any of the other variables in the system. This is intuitive. In addition when testing for stochastic trends in this system for all countries in the sample we could think of one real and one nominal stochastic trend. The real trend could be thought as productivity driving the Y_t variable while the nominal trend could come etiher from the i_t or from π_t. Reasons for saying that the second nominal trend is coming from the π_t are two. The first is that in the two-variable VEC with only π_t and i_t included the stochastic trend is coming from the π_t for the majority of the countries (of course both of the variables cointegrate) and the second that it is unlikely that an increase in the i_t would have a permanent effect on the other variables in the system. So, from the long-run matrix and from cointegration relationships we have six linearly independent restrictions, because from the reduced rank of $C(1)$ has reduced rank $(rk(C(1)) = 2)$, only two equations are linearly independent, which gives $kr = 6$ linearly independent restrictions. To identify the $k = 3$ permanent shocks, $k(k-1)/2 = 4$ additional restrictions are needed. So we need four more in the short run matrix to identifiy the shocks. The remaining four restrictions are imposed based on the decision lags in the fiscal policy (reasoning the same as above). Therefore we impose that shocks in T_t, Y_t and i_t have no impact on the G_t within a quarter and in addition that i_t has no impact on T_t within a quarter. Thus, sVEC model is just-identified. This is intuitive and was used already by Perotti (2002).

The two just-identified structural VEC models are estimated with the method shown in section 3.

7 Impulse response analysis

Impulse responses are shown for the countries in the sample. Confidence intervals for the impulse responses in this paper will be bootstrapped by procedure as described in Breitung, Bruegemann and Lütkepohl (2003). Bootstraps from percentile method proposed by Hall (1992) will be used to construct the 95% confidence intervals.

The impulse responses in the figures below have to be interpreted as response of the variables to a one standard deviation shock in the two fiscal variables. To interpret the response as a percentage change, one has to multiply the impulse responses by one hundred (or multiply initial variables in the analysis by one hundred).

The results of a fiscal shocks are quite heterogenous across the countries in the sample. As a rule for the 5-variable sVEC in most countries, a positive government spending shock (G_t) has a positive effect on the output for Finland, Austria, Italy, United States especially up to the year 1983, Australia and Canada. For Germany the effect of the government spending shock appears to be insignificant, as also for United states after the period of 1983.

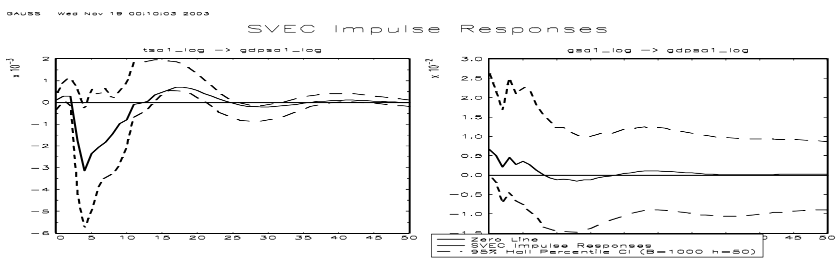
As for the tax shock, in the 5-variable VEC it appears that a positive tax shock has a negative effect in Italy, United States in both periods and in Australia. In other countries the response is insignificant.

As with respect to the difference of three- and five-variable systems, the difference between impulse responses is large for Finland for both variables, where especially a tax shock becomes from a negative to an insignificant, Germany for taxes, Austria for tax shock, which becomes insignificant, United States for shocks in both variables in the period after the year 1983, Australia for shocks in both fiscal variables included in the system, Canada for tax shock which becomes insignificant and the same for Great Britain. Therefore, inclusion of two additional financial variables is important in our sample and there would be important to include some more, especially the exchange rate and the money supply into the analysis.

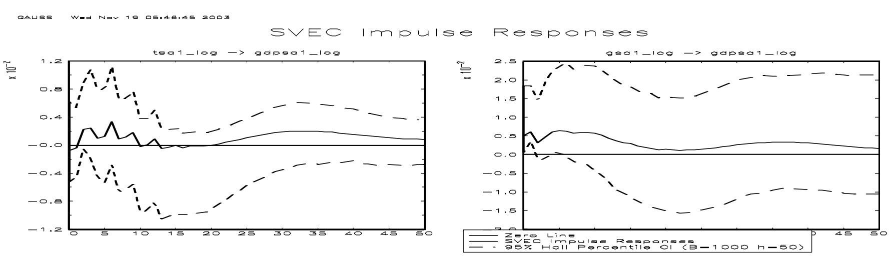
From our analysis a positive 1% government spending shock increases Y_t at most by 0.5% at the impact in Finland, 0.5% after 8 quarters in Austria, 0.3% after 4 quarters in Italy, 0.21% at the impact in USA up to 1983, 0.7% at the impact for Australia and 0.5% two years after impact in Canada and 0.5% one year after impact in Great Britain.

7.0.1 Finland

3-variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

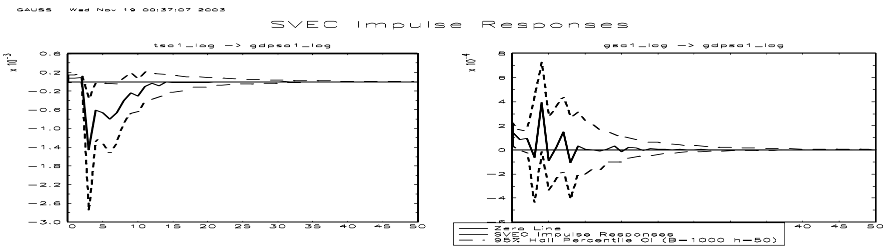


Five variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

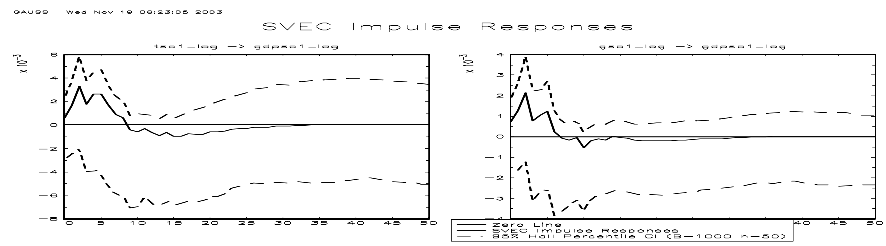


7.0.2 Germany

3-varable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

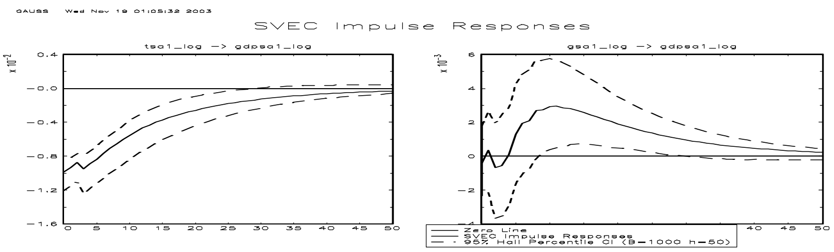


Five variable VEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

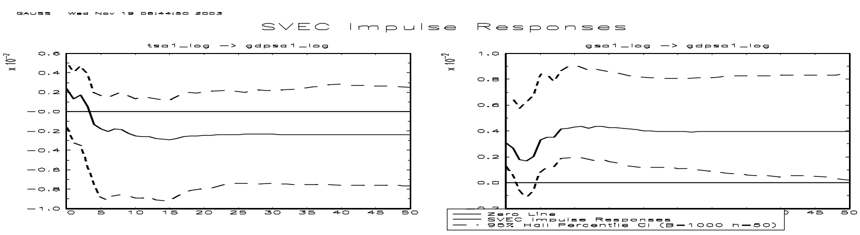


7.0.3 Austria

3-variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

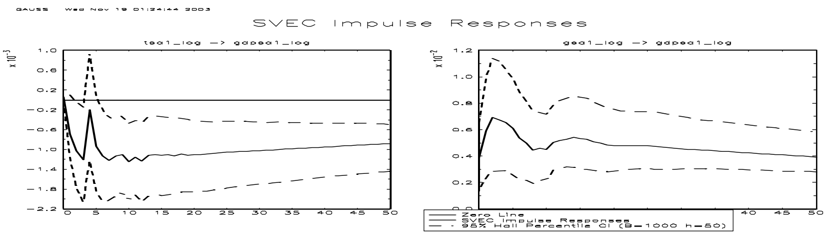


5-variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

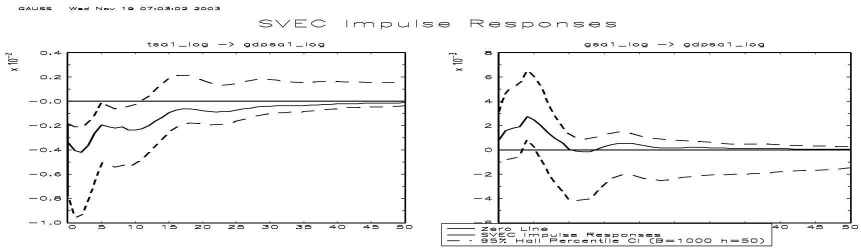


7.0.4 Italy

3-variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

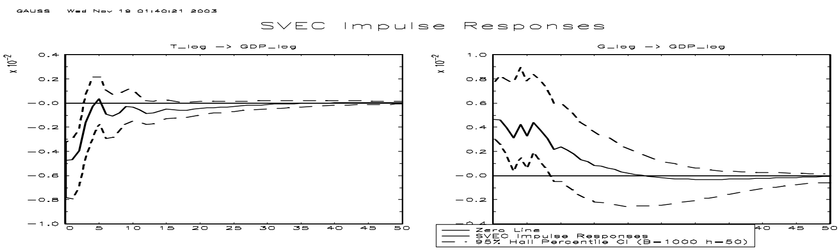


5-variable VEC impulse responses (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

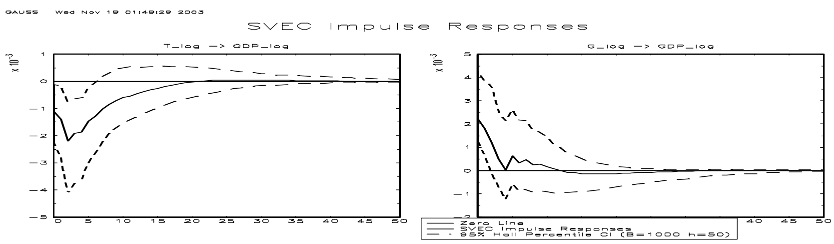


7.0.5 United States

3-variable VEC to fourth quarter 1982 (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

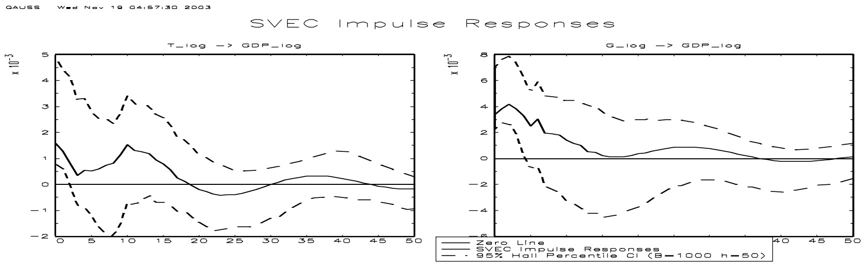


3-var VEC from the first quarter 1983 (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

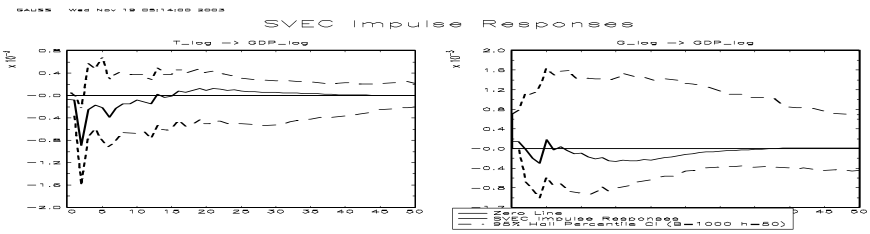


7.0.6 United States

Five variable VEC model to fourth quarter 1982 (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

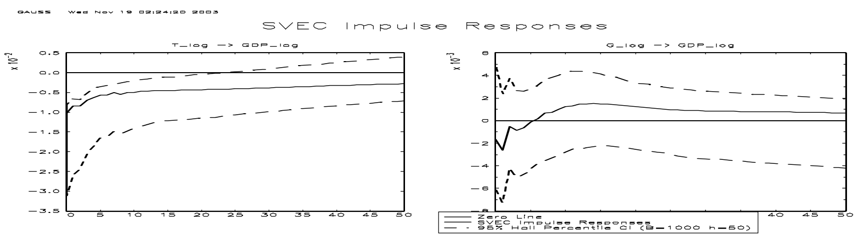


Five variable sVEC model from first quarter 1983 (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

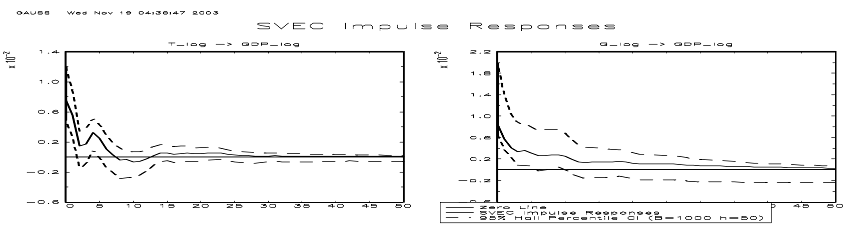


7.0.7 Australia

Three variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

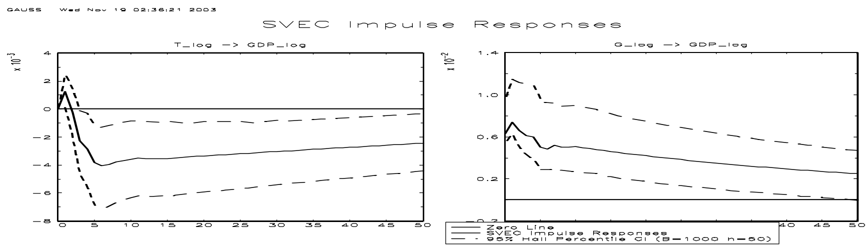


Five variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

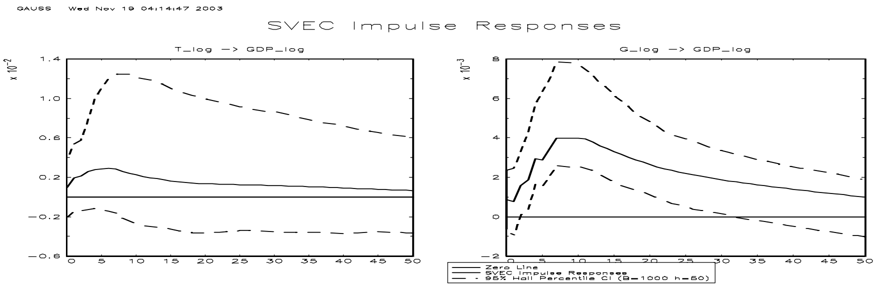


7.0.8 Canada

3-variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

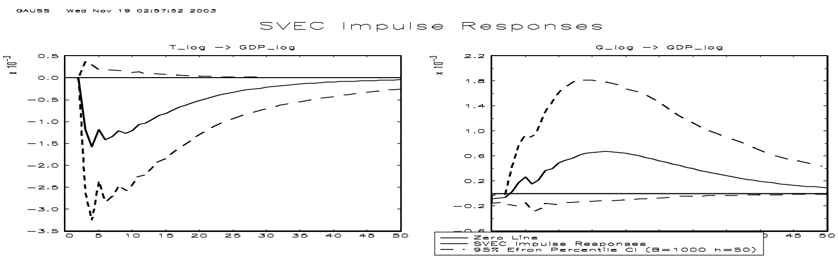


Five variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)

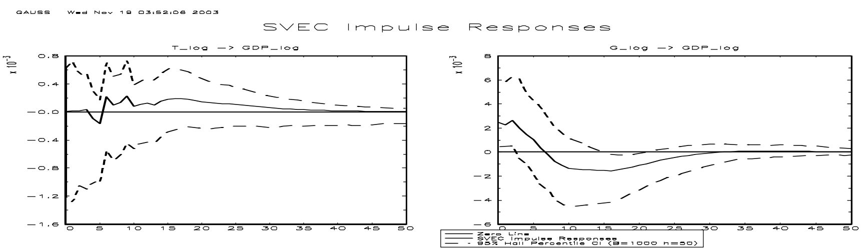


7.0.9 Great Britain

3-variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)



Five Variable sVEC impulse response (left panel response of Y_t to ϵ_T,right panel response of Y_t to ϵ_G)



8 Conclusions

This paper estimates the effects of fiscal policy in the structural Vector Error Correction (sVECM) model in the five variable system with government activity (Y_t), government spending (G_t), taxation (T_t), interest rate (i_t) and inflation (π_t) for four EMU countries (Austria, Germany, Finland and Italy) and for four non-EMU OECD countries (USA, Australia, Canada and Breat Britain).

Identification of a tax shock ϵ_{T_t} and a government spending shock ϵ_{G_t} is acchieved by distinguishing between permanent and temporary shocks. Inference on temporary shocks is drawn from cointegration analysis first of three variables system (Y_t, T_t, G_t) where Y_t appears as a stochastic trend in all countries and where the two cointegrating relationships are defined as a solvency rule and as a automatic stabilisation rule. To acchieve just-identification of the shock the assumption of residual tax determination within a quarter (Beetsma and Bovenberg 1998) was used. In the five variable system $(\pi_t, T_t, Y_t, i_t, G_t)$ the third cointegration relationship was identified as a Fisher relation, and the second stochastic trend was identified as coming from inflation (π_t). In addition decision lags in fiscal policy were used to just-identify the system.

In the paper some newer findings in the VAR literature were used. The lag-length of the sVEC was determined with the help of residual diagnostics criteria (for autocorrelation, non-normality and ARCH) and the exclusion of insignificant lags was used according to the top-down algorithm with respect to the Akaike information criterion. Impulse response bands were bootstrapped with the Hall (1992) confidence bounds. Estimation of the long- and short-run structural parameters was performed using the ML approach with the Amisano-Giannini (1997) algorithm.

From our analysis a positive 1% government spending shock increases Y_t at most by 0.5% at the impact in Finland, 0.5% after 8 quarters in Austria, 0.3% after 4 quarters in Italy, 0.21% at the impact in USA up to 1983, 0.7% at the impact for Australia and 0.5% two years after impact in Canada and 0.5% one year after impact in Great Britain.

For extension more variables should be included in the sVEC (e.g. exchange rate), and the ARCH in the two financial series (π_t, i_t) should be corrected for.

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10 Appendix A: Cointegration tests

Table: Cointegration analysis of the 3-variable VEC systems

Country	Period	Lags included*	Johansen Trace test	p-value
Canada	1961q1 2001q4	2 (2,2)	$r = 0$	0.00
			$r = 1$	0.05
			$r = 2$	0.68
Australia	1963q2 2001q2	4 (4,4)	$r = 0$	0.00
			$r = 1$	0.06
			$r = 2$	0.24
Great Britain	1963q1 2001q2	4 (4,2)	$r = 0$	0.02
			$r = 1$	0.05
			$r = 2$	0.21
USA-whole sample	1960q1 2001q4	4 (4,4)	$r = 0$	0.00
			$r = 1$	0.01
			$r = 2$	0.39
USA	1960q1 1982q2	1 (1,1)	$r = 0$	0.00
			$r = 1$	0.01
			$r = 2$	0.17
USA	1983q1 2001q4	3 (3,1)	$r = 0$	0.00
			$r = 1$	0.01
			$r = 2$	0.73
Austria	1964q1 1998q4	4 (4,4)	$r = 0$	0.00
			$r = 1$	0.01
			$r = 2$	0.15
Italy	1960q1 1998q4	2 (3,2)	$r = 0$	0.00
			$r = 1$	0.08
			$r = 2$	0.23
Finland	1970q1 1996q4	10 (10, 10)	$r = 0$	0.00
			$r = 1$	0.01
			$r = 2$	0.30

Country	Period	Lags included	Saikkonen&Lütkepohl test	p-value
Germany	1966q1 1998q4	2 (3,2)	$r = 0$	0.00
			$r = 1$	0.00
			$r = 2$	0.37

Notes:

* lags included as suggested by Akaike information and Final prediction error criterion

11 Appendix B

Cointegration tests for five-variable systems.

Notes:

+ - Four criteria for optimal number of lags used are Akaike info criterion, Final prediction Criterion, Hannan-Quinn criterion, and Schwarz criterion. They are taken from JMulti software.

Deterministic term included was a constant only.

Critical values from Johansen (1995a, Table 15.4.) and from Lanne et al. (2002).

Johansen Trace test+			Johansen Trace test+		
		p-value			p-value
Canada	r=1	0.00	Austria	r=1	0.00
	r=2	0.03		r=2	0.03
	r=3	0.18		r=3	0.09
	r=4	0.34		r=4	0.21
Australia	r=1	0.00	Finland	r=1	0.00
	r=2	0.02		r=2	0.01
	r=3	0.21		r=3	0.26
	r=4	0.28		r=4	0.28
USA to 1982	r=1	0.00	Italy	r=1	0.00
	r=2	0.02		r=2	0.01
	r=3	0.08		r=3	0.33
	r=4	0.23		r=4	0.38
USA from 1983	r=1	0.00	Saikkonen&Lütkepohl test+		
	r=2	0.01			p-value
	r=3	0.23	Germany	r=1	0.01
	r=4	0.27		r=2	0.03
Great Britain	r=1	0.00		r=3	0.09
	r=2	0.02		r=4	0.18
	r=3	0.21			
	r=4	0.38			