Fiscal Expenditure Shocks in a Structural VAR and ADAM

Peter Agger Troelsen*

Abstract: We compare temporary fiscal expenditure shocks in ADAM to a SVAR using impulse response analysis of the following variables; the real wage, the unemployment rate, private consumption, and a measure of foreign trade. Our primary focus is the difference of the models with respect to crowding out time and dynamics of the unemployment rate. We find that ADAM crowds out the initial unemployment response at least as fast as the SVAR. If we finance the fiscal expansion via income taxes in ADAM, the crowding out process becomes even faster. In general, the dynamics of ADAMs variables are within the statistical uncertainty of the SVAR, and in that sense the models behave alike. As a robustness check, we compare ADAM to the SVAR in Ravn and Spange (2014), which focuses on GDP instead of unemployment; this comparison confirms our conclusion on ADAMs crowding out time. We also note that the SVAR analysis does not indicate a strictly positive reaction in private consumption to an expansionary fiscal shock, suggesting that expenditure shocks are tax-financed or that consumers are partly Ricardian. Based on our study, we argue that ADAMs crowding out time should not be reduced.

Keywords: Fiscal Expenditure Shocks; Model Benchmarking; ADAM

JEL: C01; E17; E62; E12

1. Introduction

The length of the crowding out process in Denmark is an ongoing topic for discussion. The mechanisms underlying the process can be more than one. Some of the

* The author wish to thank two anonymous referees, Heino Bohn Nielsen, Ellen Andersen, colleagues from Statistics Denmark and, especially, Dan Knudsen for useful comments and discussions. The views expressed in this paper are those of the author and do not necessarily reflect the viewpoints of the Modelling Group or Statistics Denmark.
Contact: agger.troelsen@gmail.com.

more obvious candidates are via foreign trade, via an economic policy reaction, and (or) via a reaction in private consumption caused by Ricardian equivalence. In this paper, we are interested in the length of the crowding out process in the Aggregated Danish Annual Model (ADAM). Some previous studies have compared the crowding out in ADAM and DREAM, SMEC, and Mona,[1] and concluded that ADAM has the longest crowding out period.[2] These comparisons have been based on permanent shocks. Further, Finansredegørelsen (2014) suggests that ADAM is also "slower" than vector autoregressions specified by the Blanchard and Quah (1989) identification.

The intention of this paper is to take a slightly different perspective using temporary rather than permanent shocks. Temporary shocks are of particular interest as, e.g., economic policy, consumer preferences, and structures change in the long run. To be precise, we are comparing the official Statistics Denmark version of ADAM[3] to a structural vector autoregression (SVAR), which can only handle temporary shocks. In the literature, SVAR models are often used to validate macro models, and we will use the SVAR to benchmark ADAMs crowding out process with respect to unemployment.

The specific choice of SVAR is inspired by Ravn and Spange (2014), and the comparison by Pedersen (2012). Our interest is the relations between the following five Danish variables; the real wage, the unemployment rate, government consumption, private consumption, and a measure of the trade balance. To compare the models, we simulate a temporary government consumption shock in the SVAR, mimic the same shock in ADAM, and compare response dynamics. We find that the crowding out mechanism is faster in ADAM than in the SVAR, and the difference increases if we finance the fiscal expansion via income taxes in ADAM. In addition, the maximal effect on unemployment is larger in the SVAR where it appears after several years, whereas it is present in the first year in ADAM. Compared to similar studies, the larger effects and the slower crowding out in the SVAR does not come as a surprise, as this is also found in Pedersen (2012), in which the Ravn and Spange (2014) SVAR is compared to Mona. Our results seem robust, as the conclusion is the same if we compare ADAM to the SVAR presented in Ravn and Spange (2014).

Obviously, there are many possible explanations for the difference between ADAM and the SVAR. One explanation could be that some of ADAMs important relations, e.g., the wage and some price equations, are estimated with parameter restrictions, which are numerically larger than their free estimates. This amplifies the crowding out channel from the labour market to foreign trade. Furthermore, there is statistical uncertainty attached to all behavioural equations in ADAM and one

1. DREAM is short for Danish Rational Expectation Model; SMEC is short for Simulation Model of the Economic Council; Mona is short for Model Nationalbank.
2. This is found in Knudsen and Gustafsson (2013) and Statistics Denmark (2012), chapter 11.
3. We refer to the model version ADAM, July 13.

should keep in mind that this uncertainty is not reflected in ADAMs multipliers. Therefore, it can be hard to tell, when ADAMs dynamics are significant, and, hence, hard to pin point the "true" crowding out time of the unemployment rate.

The rest of our paper is organized as follows: In section 2, we present the SVAR and data, and in section 3 we present the identification scheme of the SVAR. In section 4 and 5, we present results of, respectively, the impulse response analysis and the robustness checks. Section 6 is a brief introduction to ADAM, and in section 7 we compare ADAM to the SVAR. In section 8 and 9 follows a discussion and a conclusion.

2. Model and data

Our starting point is the following SVAR:[4]

$$Y_t = \sum_{k=1}^{m} \alpha_k Y_{t-k} + \sum_{j=0}^{l} \beta_j X_{t-j} + \Theta_0 + \Theta_1 T + \Theta_2 EC + u_t \qquad (1)$$

In equation (1), Y_t is a vector of endogenous variables. $\sum_{k=1}^{m} \alpha_k Y_{t-k}$ is a sum of lagged endogenous variables, Y_{t-k}, multiplied by a vector of coefficients, $\alpha_{k.}$ $\sum_{j=0}^{l} \beta_j X_{t-j}$ is a sum of exogenous variables, X_{t-j}, multiplied by a vector of coefficients, β_j. Θ_0, Θ_1 and Θ_2 are vectors of constants, coefficients to the linear time trends, T, and coefficients to the crisis dummy, EC. We set the crisis dummy equal to 1 from the fourth quarter of 2008 as in Ravn and Spange (2014). u_t is an error term, which can be written as $A_0^{-1}\varepsilon_t$. Here A_0 is a matrix containing the parameters of the contemporaneous relation between the endogenous variables and ε_t is a vector of structural shocks. The vector of reduced form error terms shall have an expected value of zero, a constant variance and be uncorrelated over time, i.e., $E(u_t) = 0, E(u_t u_\tau') = \sum_u$ for $\tau = t$ and $E\,(u_t u_\tau') = 0$ for $\tau \neq t$.

The vectors of endogenous and exogenous variables look as follows:

$$Y_t' = (E\,AGDP_t, RW_t, GC_t, UR_t, C_t, EM_t), X_t' = (USGDP_t)$$

In the endogenous vector, Y_t, $EAGDP_t$ is real GDP in the euro area, and RW_t is the real wage defined as the nominal wage deflated by consumer prices. GC_t is real government consumption, UR_t is the unemployment rate, C_t is real private consumption, and EM_t is the ratio of exports over imports in fixed prices. The last five variables in the endogenous vector are fully endogenous Danish variables, while the first variable, GDP in the euro area, is modelled without feedback from the

4. The SVAR calculations were made in R using – mainly – the package VARS described in Pfaff (2008).

Danish variables.[5] In X_t, we have the strictly exogenous variable GDP in the US, $USGDP_t$, which is included to control for global shocks. All variables enter the system in log-levels except for the unemployment rate and the ratio of exports over imports, which are in levels.

In the analysis, we use seasonally adjusted quarterly data. All variables come from the Mona database except for euro area GDP and US GDP, which are, respectively, from the Area-wide model database and the database of Federal Reserve Bank of St. Louis. Graphs of the time series can be found in appendix A.

Before estimating the VAR, we inspect the variables for non-stationarity using an augmented Dickey-Fuller (ADF) test. Based on graphical inspection, we include constants in all level tests and time trends when appropriate. For the difference tests we include only constants. The results are reported in table 1 in appendix B. When the variables enter the ADF-test in levels the null hypothesis cannot be rejected at a 5 percent significance level for any variable. When the variables are in differences the null is rejected in all cases. Thus, we conclude that the variables in levels are integrated of order one.

In the SVAR analysis, we abstain from an explicit co-integration analysis, as we can estimate our system consistently also when the variables are non-stationary, cf. Hamilton (1994) ch. 20, and as this approach is commonly used in related studies.[6] The model is estimated on data from 1st quarter of 1983 to 4th quarter of 2011, so Denmark follows a fixed exchange rate regime throughout the sample.

To choose the number of lags in the model, we apply a standard LM-test with a χ^2-distribution and an LM-test with an *F*-distribution (LMF); both tests concern autocorrelation. The LMF-test works as a small sample correction of the LM-test.[7] We test for serial correlation up to the 1st and 4th lag. The LMF-test suggests more than one set of lags, as several p-values are above a 5 percent significance level, cf. table 2 in appendix B. On the other hand, the LM-test suggests 3 lags for the endogenous variables, and up to 1 lag for the exogenous variables, cf. table 2. We proceed with this lag set and test its residuals for ARCH and normality. The multivariate ARCH-test shows no sign of heteroscedastic errors, but the multivariate Jarque-Bera (JB) test rejects normality, cf. table 3. An inspection of the equation specific JB-tests indicate that the euro area GDP and the government consumption equation causes the rejection. Therefore, we choose to include two dummy variables[8] in the model. Now, the multivariate normality test cannot be rejected at a 5

5. As in Ravn and Spange (2014), though, they use a weighted average of GDP in Germany and Sweden instead of euro area GDP.
6. See, e.g., Ravn and Spange (2014), Blanchard and Perotti (2002) and Heppke-Falk et al. (2006).
7. Juselius (2006), ch. 4, describes a small sample for quarterly macro models to lie between 50 to 100 observations, which is close to our sample size of 116.
8. The first dummy accounts for negative residuals in the euro area GDP equation in the 3rd quarter of 1986, in the 3rd quarter of 1988 and in the 2nd quarter of 2008. The second dummy is

percent significance level, cf. column (5) in table (3). Most of the LM-tests show no sign of autocorrelation,[9] and the multivariate ARCH-test do not indicate any heteroskedasticity, cf. column (3) in table (3). We decide to continue with a model, which applies a set of deterministic terms including dummies, and uses 3 and up to 1 lag of, respectively, the endogenous and exogenous variables.[10]

3. Identification

To identify the causal relation between the – unobservable – structural shocks in and the endogenous variables, we have to identify the relation between the structural and reduced form error terms. This may be done in more than one way. We choose a structural identification, inspired by Ravn and Spange (2014). Our staring point is to write the matrix equation $A_0 u_t = \varepsilon_t$ as:

$$u^{EAGDP} = a_1 u^{RW} + a_2 u^{GC} + a_3 u^{UR} + a_4 u^{C} + a_5 u^{EM} + \varepsilon^{EAGDP} \quad (2)$$

$$u^{RW} = b_1 u^{EAGDP} + b_2 u^{GC} + b_3 u^{UR} + b_4 u^{C} + b_5 u^{EM} + \varepsilon^{RW} \quad (3)$$

$$u^{GC} = c_1 u^{EAGDP} + c_2 u^{RW} + c_3 u^{UR} + c_4 u^{C} + c_5 u^{EM} + \varepsilon^{GC} \quad (4)$$

$$u^{UR} = d_1 u^{EAGDP} + d_2 u^{RW} + d_3 u^{GC} + d_4 u^{C} + d_5 u^{EM} + \varepsilon^{UR} \quad (5)$$

$$u^{C} = e_1 u^{EAGDP} + e_2 u^{RW} + e_3 u^{GC} + e_4 u^{UR} + e_5 u^{EM} + \varepsilon^{C} \quad (6)$$

$$u^{EM} = f_1 u^{EAGDP} + f_2 u^{RW} + f_3 u^{GC} + f_4 u^{UR} + f_5 u^{C} + \varepsilon^{EM} \quad (7)$$

To solve this system we must impose a set of restrictions. We start by assuming that euro area GDP is unaffected by the Danish variables, so $a_1 = a_2 = a_3 = a_4 = a_5 = 0$. The real wage is assumed only to be affected by its own shock, as nominal wage and price formations are sticky, consequently $b_1 = b_2 = b_3 = b_4 = b_5 = 0$. Using the description in Perotti (2005), government consumption shocks can be seen as a linear combination of three different shocks: (i) the automatic response of government consumption to the macro variables, (ii) the systematic, discretionary

equal to one in the 2nd quarter of 1987 and in the 2nd quarter of 1996 and captures large residuals in the government consumption equation.

9. The p-values: LMF(1) = 0.28, LMF(4) = 0.42, LM(1) = 0.07, LM(4)= 0.01.
10. Graphs of residuals, correlations, and partial correlations can found in appendix A.

response of government consumption to the macro variables, and (iii) the random, discretionary fiscal policy shocks. Following Blanchard and Perotti (2002), Ravn and Spange (2014) and others, we assume that government consumption do not react immediately to the other macro variables on a discretionary basis, because fiscal authorities need more than a quarter to react to macro developments; this rule out (ii). Furthermore, we assume away any automatic response of government consumption to the unemployment rate within a quarter. A similar assumption is often found in related studies, which use GDP instead of the unemployment rate.[11] This assumption makes (i) irrelevant, and without fiscal shocks of type (i) and (ii), we can set $c_1 = c_2 = c_3 = c_4 = c_5 = 0$. In section 5 we shall make a robustness check, where c_3 is estimated and included in the identification.

The unemployment rate is allowed to react to contemporaneous government consumption shocks, but not to the other variables, hence $d_1 = d_2 = d_3 = d_4 = d_5 = 0$. The idea is that fiscal authorities can directly affect public employment and therefore total unemployment, but the effects of for example a private consumption shock on the unemployment rate are more indirect and lagging, as it may take more than a quarter for a firm to adjust its employment level as a reaction to higher demand. Private consumption is assumed to be unaffected by shocks to euro area GDP and to exports over imports, but allowed to react immediately to shocks to the other variables, so that $e_1 = e_5 = 0$. Finally, exports over imports, which repeats net exports in fixed prices, is expected to respond to all other variables within a quarter, making it the most endogenous variable in the model. Implementing all restrictions, we can simplify equation (2-7) to:

$$u^{EAGDP} = \varepsilon^{EAGDP} \tag{8}$$

$$u^{RW} = \varepsilon^{RW} \tag{9}$$

$$u^{GC} = \varepsilon^{GC} \tag{10}$$

$$u^{UR} = d_3 u^{GC} + \varepsilon^{UR} \tag{11}$$

$$u^{C} = e_2 u^{RW} + e_3 u^{GC} + e_4 u^{UR} + \varepsilon^{C} \tag{12}$$

$$u^{EM} = f_1 u^{E\,AGDP} + f_2 u^{RW} + f_3 u^{GC} + f_4 u^{UR} + f_5 u^{C} + \varepsilon^{EM} \tag{13}$$

11. See, e.g., Ravn and Spange (2014) or Ravnik and Zilic (2010).

The remaining coefficients can be estimated using the reduced form residuals from the model estimated in the previous section. To estimate (11), we use ε^{GC} as an instrument for u^{GC}, and obtain the residual. We estimate (12), by regressing u^{C} on u^{RW}, u^{GC} and the residual determined by (11), which by assumption and construction is uncorrelated with u^{GC}. Equation (13) is estimated like (12), but we use the residual from regression (12) as an instrument for u^{C}.

The estimated coefficients are available in appendix C. Now, we have identified all coefficients in (8) – (13) and are able to calculate the effects of a shock to the SVAR.

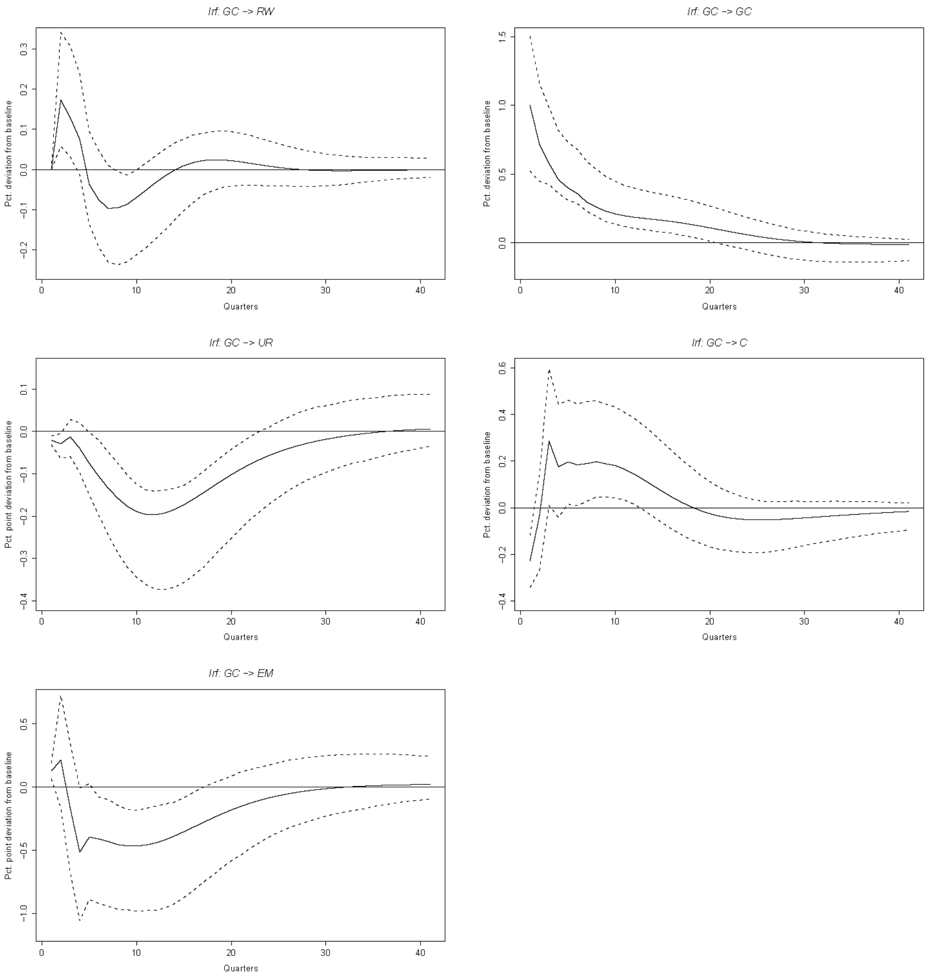
4. Impulse response analysis of SVAR

The effects of a government consumption shock to the SVAR are shown in figure 1, where the solid lines are response functions using the structural identification, and the dashed lines are Hall (1992) 95 percentile bootstrapped confidence intervals (henceforth: CI).[12] The CIs are based on 5000 replications.

The government consumption shock is a 1 percent shock in period 1, and because of the autoregressive structure of the VAR, the initial rise in government consumption slowly disappears over time. In the first period, the shock decreases private consumption and increases exports over imports. After a few quarters the effects reverse and consumption rises while exports over imports starts to fall. The initial negative response of consumption suggests short term tax-financing or Ricardian behaviour of consumers as found in Ravn and Spange (2014), however, in our SVAR the effect becomes positive after a few quarters. We will return to the effect on private consumption in the section on robustness checks.

The unemployment rate falls initially, and the peak effect is present three years later. After approximately 5 years, the effect is no longer significant, and the effect becomes zero 9 years after the shock. Due to the shock, the real wage increases a little from the first to the second quarter, but this effect disappears after 2-3 quarters. We expected a stronger, more pro-cyclical and Phillips-curve driven effect on the real wage reflecting the contraction of unemployment. Instead, the crowding out via real wages looks rather modest in the SVAR. A differently defined real wage may be a more integrated part of the crowding out mechanism in a differently specified SVAR. However, the impact on the unemployment rate seems clear enough, so we keep the estimated model, but conduct some robustness checks in the next section.

12. We have transformed the Efron and Tibshirani (1993) bootstrapped confidence intervals to Hall (1992) confidence intervals based on the description in Lütkepohl (2006).



Notes: Solid line is impulse response function from the structural identification.
The black dashed lines are 95 percent confidence intervals made using the bootstrap methodology from Hall (1992).
Irf is short for impulse response function.

Figure 1: Impulse response functions

5. Robustness checks

In this section, we present a robustness analysis, which consists of 6 separate checks presented in two seperate figures.

Figure 2 shows the effect of shocks to government consumption and each line represents the baseline model, the model presented in previous section, with a new "feature". The response of the baseline model is the black solid line. The grey dashed line is a model, where we allow government consumption to react immediately to the unemployment rate, so that the coefficient, c_3, is allowed to be non-zero. We have estimated c_3 to -0.41, which suggests that government consumption was pro-cyclical. However, the estimate is insignificant, so it is not obvious that government consumption reacts contemporaneously to unemployment.[13] Anyway, it does not make much difference to include the c_3 estimate, as the solid black and grey dashed lines are difficult to differentiate in figure 2.

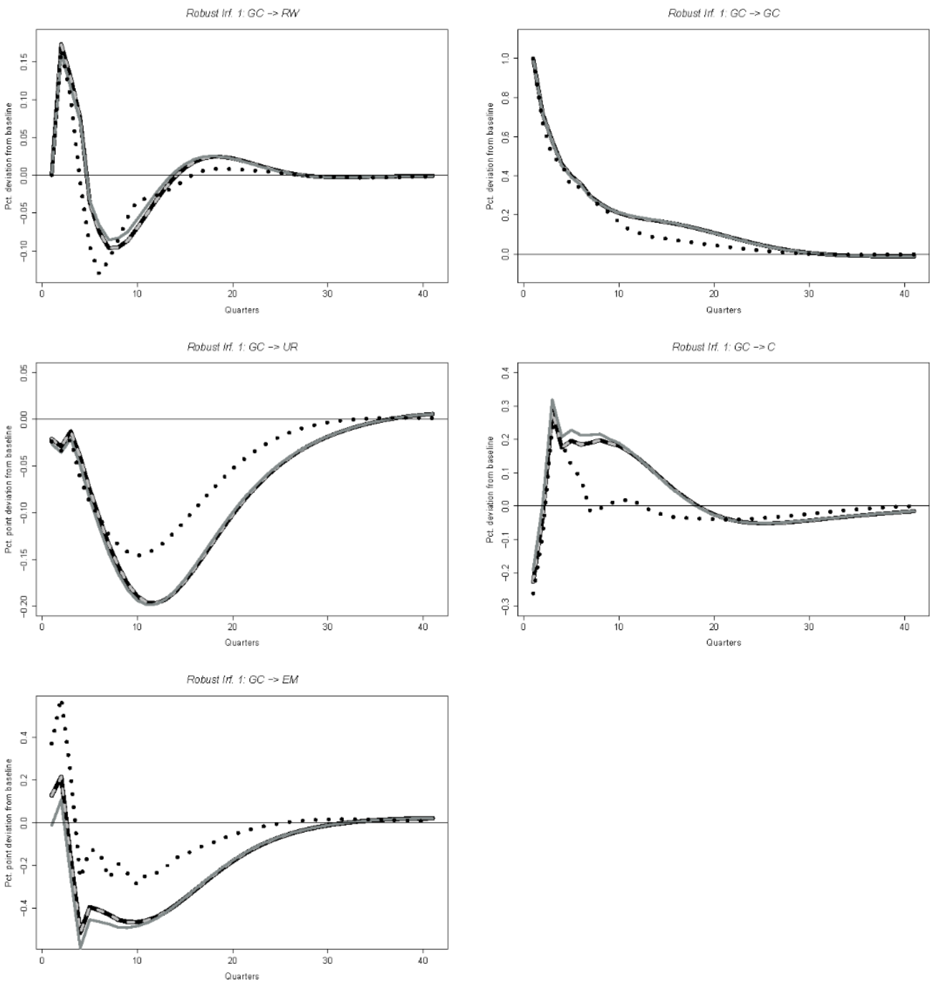
The solid grey line represents the model identified using a Cholesky decomposition of the variance-covariance matrix.[14] The Cholesky identification dictates a recursive causal structure among the variables. According to figure 2, it does not make much difference to the results, whether we use our baseline or a Cholesky identification. The black dotted line represents a model with 4 and 2 lags of the endogenous and exogenous variables, respectively. The larger model reacts similarly to the baseline SVAR, however, the reactions are more volatile and the effects disappear 3-4 quarters faster. Hence, the crowding out period is a little shorter with the larger model compared to the baseline SVAR.

Figure 3 presents the rest of our robustness analysis. The black solid line is once again our baseline SVAR. The black dashed line represents a model where the unemployment rate has been replaced by real GDP (denoted; FY). For this model, we find a positive impact on GDP from a government consumption shock. The impact and cumulative multipliers, i.e., the initial and cumulative effect of government consumption on GDP,[15] are 1.15 and 1.51, respectively. These multipliers are similar to the impact and cumulative multipliers around 1.3 in Ravn and Spange (2014), but higher than the multipliers estimated in Ilzetzki et al. (2011). Ilzetzki et al. (2011)

13. We note that our estimation is based on a rather simple approach; see appendix D.
14. For a Cholesky decomposition of the variance-covariance matrix of the reduced form residuals, the matrix, $\sum_{u}$, can be represented by PP', where P is a $6\chi6$ lower triangle matrix with stan- dard deviations of the reduced form residuals in the main diagonal, covariances below and zeros above. Using $u_t = A_0^{-1}\varepsilon_t$ the variance-covariance matrix of u_t can be written as: $\sum_u = A_0^{-1} \sum_\varepsilon A_0^{-1}$. Setting $\sum_\varepsilon = DD'$, where D is a diagonal matrix with the same main diagonal as P, we get; $PP' = \sum_u = A_0^{-1} \sum_\varepsilon A_0^{-1} = A_0^{-1} DD' A_0^{-1} \longrightarrow A_0^{-1} D = P \longrightarrow A_0 = DP^{-1}$, which means that $A_0 u_t = \varepsilon_t$.
15. We have calculated the cumulative multiplier over a 25 quarter time horizon, but a 40 quarter horizon would hardly change the result. The impact multiplier is: $\frac{\Delta GDP_1}{\Delta GC_1}$ and the cumulative multiplier is: $\frac{\sum_{t=1}^{25}\Delta GDP_t}{\sum_{t=1}^{25}\Delta GC_t}$ (Ilzetzki et al. (2011)), as we shock in period 1. ΔX_t refers to the deviation of X_t from its baseline in period t.

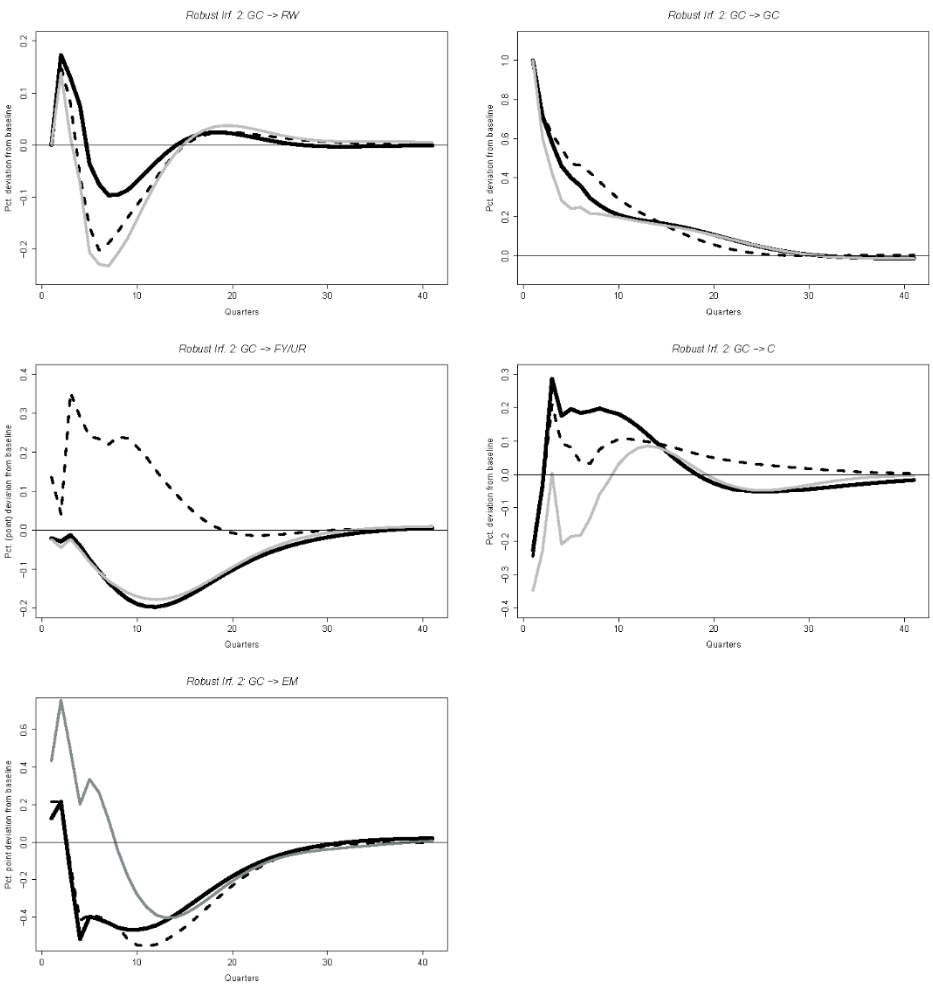
report impact multipliers of only 0.37 and 0.09 for high income countries and fixed exchange rate regimes, respectively, but they report cumulative multipliers of 0.80 and 1.50 for the same country groups and this is close to ours.

The grey solid line represents a model, which is estimated without the financial crisis period after 2007. With this model, it seems that consumers behave more Ricardian-like, as the effect on private consumption stays negative for a longer period following a government consumption shock or the shock to government consumption may be more tax-financed when the economy is strong. We could argue that excluding the 4 years of crisis from the sample makes the estimated model more likely to represent a "boom" regime and the effect on private consumption may be regime-dependent as found in Auerbach and Gorodnichenko (2012) for the US economy. All in all, our baseline SVAR is not that sensitive to changes, so our results seem robust.



Notes: The black solid line is from the structural identified model. The grey dashed line is from the model in which government consumption reacts to the unemployment rate in the shock period. The grey solid line is from the model identified using a Cholesky decomposition of the variance-covariance matrix. The black dotted line is from the model with 4 and 2 lags of the endogenous and exogenous variables, respectively. No confidence intervals are provided.

Figure 2: Robustness analysis 1



Notes: The black solid line is from the structural indentified model. The black dashed line is from the model where the unemployment rate is replaced by real GDP. The grey solid line is from the model estimated without the crisis period.
No confidence intervals are provided. FY is real GDP.

Figure 3: Robustness analysis 2

6. A short introduction to ADAM

The applied ADAM version consists of approximately 3500 variables of which 2500 variables are endogenous. Out of the 2500 equations, about 90 are estimated behavioural equations. The rest are identities or technical relations providing for example disaggregated tax revenues for the public sector or materials for industries in the input-output system of the model. The size of ADAM prevents us from deriving a reduced form. Instead, ADAM is solved numerically by the Gauss-Seidel algorithm.

ADAM can be characterized as a Keynesian model with long term neo-classical properties, so that demand shocks can have only temporary effects on production and employment while supply shocks can have permanent effects. ADAM does not have an endogenous fiscal reaction function or forward looking expectations, and as Denmark has a fixed exchange rate vis-à-vis the euro, monetary policy and interest rates are exogenous and dictated by the euro area. The inflation rate is also given from abroad in the long run.

When ADAM is in disequilibrium, unemployment is corrected towards its structural level via the impact of unemployment on wage, which spill over to Danish competitiveness, net exports and market shares, and back to the aggregated demand for goods and labour. This means that crowding out in ADAM is largely determined by how strongly foreign trade reacts to the Danish labour market.

ADAMs parameters are estimated using mainly error correction models, for which some coefficients are restricted within the range of statistical uncertainty. The results in ADAM are sensitive to how the relations are specified and estimated. A new specification with new explanatory variables, another estimation period or new parameter restrictions, may change ADAMs multipliers and the crowding out period. We believe that the results reported in this paper for the Statistics Denmark July 2013 model version are also relevant for newer versions of ADAM.

7. Comparing ADAM to the SVAR

We shall compare the baseline SVAR model to ADAM[16] over a ten year period following a government consumption shock. To do so, we have transformed the quarterly impulse response functions from the SVAR to an annual frequency.

Since government consumption is endogenous and aggregated in the SVAR, and since ADAM do not have a built-in fiscal reaction function, we also have to specify the shock to government consumption and decide whether and how the shock should be financed.

16. ADAM is simulated in GEKKO using the official model version July 2013 developed by the macroeconomic modelling unit of Statistics Denmark.

In ADAM, a government consumption shock can come from more than one source, as government consumption is a function of public employment, government purchases of goods and services from the private sector, and government reinvestments. The latter component is rather small and will be ignored. However, to make sure that our results are robust, we shock ADAM via government purchases of goods and services and also via public employment. In combination to the expenditure shock, we apply the following three tax-financing setups:

(1) No finance; (2) Financing which starts in the shock period and ends ten years after; (3) Financing which starts two years after the shock and lasts for ten years. In (2) and (3) we have adjusted income taxes to make the public debt to GDP ratio unaffected in the long run. However, the change in public consumption is temporary, which moderates the need for tax increases and makes the question of financing less crucial. To sum up, we make two ADAM experiments with three different financing setups.

The results of the comparison are shown in figure 4, where the black solid and dotted lines are, respectively, the SVAR impulse response functions and confidence intervals. The light grey solid and dotted lines are ADAM experiments with no financing and financing starting in year 2. The dark grey solid line is an ADAM experiment with financing starting in the shock period.

The positive shock to government consumption initially increases the real wage in both the SVAR and ADAM. However, the real wage response in the SVAR starts to fluctuate and returns to its baseline around year 7 while it remains positive in ADAM. This difference between the SVAR and ADAM looks significant around year 3, where the ADAM response is outside the 95 percent confidence interval of the SVAR. For the rest of the period, the ADAM response to the tax-financed shock lies inside the confidence interval, implying that the difference to the SVAR is insignificant. The difference indicates that in the SVAR, the unemployment effect is not really crowded out by higher wage costs.

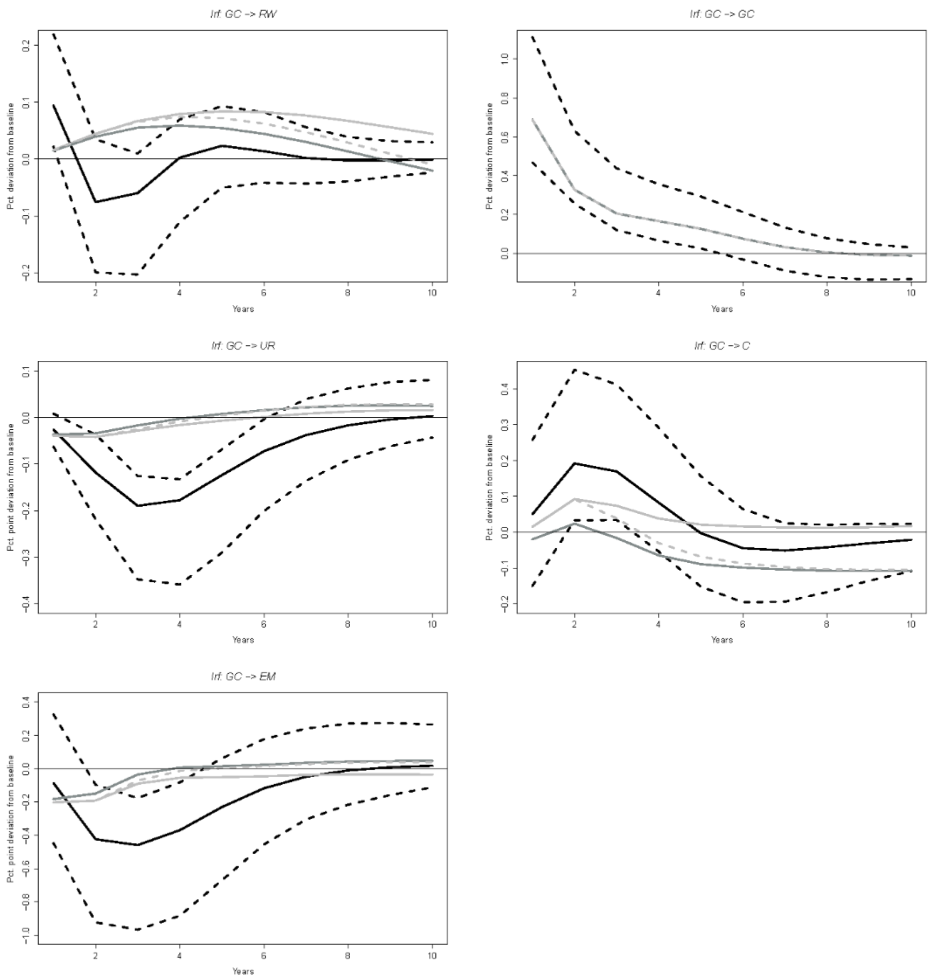
The effect on the unemployment rate has the same sign in the SVAR and ADAM, but in the SVAR, it takes a couple of years before the effect peaks while the effect in ADAM peaks in the first year. The unemployment effect is crowded out after approximately 5 years in ADAM. In the SVAR, the effect on the unemployment rate becomes insignificant after approximately 6 years and the response function intersects the zero line after 10 years. In the tax-financed ADAM experiments, the crowding out of the unemployment rate is faster than in the unfinanced experiment, as higher taxes reduce private consumption and aggregate demand.

The first year effect on private consumption is positive in the SVAR and in the unfinanced ADAM calculation. The private consumption effect of the latter ADAM calculation remains within the 95 percent confidence interval of the SVAR, but private consumption fluctuates more in the SVAR. We note that if the additional government consumption is financed from the beginning, private consumption will fall in year 1 in ADAM. In general, the impact of tax-financing on the crowding out of the unemployment is not crucial because the change in public consumption is temporary, which moderates the need for tax increases.

The first year impact on the ratio of exports over imports is negative in all models, but in ADAM the impact vanishes over the following years. In the SVAR, the negative impact peaks in year 3 and the difference to ADAM becomes significant. However, the stronger negative reaction in foreign trade does not mean that the SVAR is faster in crowding out. Another general observation is that the peak effect is larger in the SVAR for all variables, except for the real wage.

As a robustness check of the government purchase shock, we have increased public employment in ADAM; the figures can be found in appendix F. The real wage response becomes a bit stronger and the unemployment effect becomes larger. However, this does not seem to change the crowding out period much, so the choice of government consumption category is not crucial for the conclusion.

As a final robustness check, we have compared ADAM to the SVAR in Ravn and Spange (2014). The comparison is illustrated in appendix G, where we show the GDP reaction to a government consumption shock. The effect on GDP remains positive for a longer period in the Ravn and Spange (2014) SVAR, but the difference to ADAM is insignificant. The effect on GDP has the same sign in the SVAR and the ADAM experiments, but the effect in ADAM is slightly smaller. The first year multiplier in Ravn and Spange (2014) is 1.15 versus 0.96 and 0.82 in ADAM when we shock, respectively, public employment and government purchases of goods and services. The first year multiplier in Ravn and Spange (2014) is 1.15 versus 0.96 and 0.82 in ADAM when we shock, respectively, public employment and government purchases of goods and services. In general, ADAM seems to be more alike with the Ravn and Spange (2014) SVAR than to our own SVAR.



Notes: The black solid and dashed lines are impulse response functions and confidence intervals from the baseline SVAR. The solid grey line is an ADAM experiment with no financing. The grey dotted line is an ADAM experiment with financing starting in the shock year. The dark grey solid line is from an ADAM experiment with financing starting two years after the shock year. The financing is set to keep the long term public debt to GDP ratio unchanged in the long term by adjustment of income taxes.

Figure 4: A positive shock to public purchase of goods and services

8. Discussion

Our results suggest that the crowding out in ADAM is not too long; oppositely, it seems too fast. One explanation for the faster crowding out could be that some of ADAMs crucial parameters have been adjusted away from their free estimates. This is, e.g., the case in the wage, the private consumption, in some price, and in the foreign trade relations. Of course it is tempting to "free" the restricted coefficients in ADAM and redo the exercise, however, this is beyond the scope of our study. We believe, freeing ADAM can make a difference, especially, when the shocks have longer duration. However, with temporary, short lived shocks, as the ones we study, we think the difference would be moderate.[17]

As mentioned above, our SVAR approach is not based on a reduced rank estimation, which means that the impulse response functions might be inconsistent at longer time horizons, cf. Phillips (1998). Thus, we might over- or underestimate the crowding out period in the SVAR. ADAMs multipliers might suffer from a similar problem, as many of ADAMs relations are estimated using error-correction models, in which the non-stationary variables do not cointegrate significantly.

That said, ADAM is an estimated model with statistical uncertainty, which is not reflected directly in its multipliers. Therefore, judging whether ADAMs dynamics are significant, and, hence, judging the "true" crowding out time following a shock can be difficult. A point for future consideration is that it may be helpful to indicate some kind of confidence intervals for the response of ADAM.

9. Conclusion

The objective of this paper has been to benchmark the response pattern of a SVAR model to ADAM following a positive temporary fiscal expenditure shock. To a large extent, the models display the same dynamics and react similarly following the shock. However, the crowding out time of the unemployment rate is faster in ADAM across robustness checks. Hence, ADAM seems to be more than sufficiently fast compared to our SVAR model and that of Ravn and Spange (2014). Ravn and Spange (2014) focus on GDP instead of unemployment, and the response of their SVAR is not significantly different from ADAMs GDP response to the same fiscal shock. Also the 1st year multiplier of GDP with respect to fiscal expenditures is close to 1 in both ADAM and the SVAR of Ravn and Spange (2014). A striking difference between ADAM and our SVAR concerns the real wage reaction to a fiscal expansion. The wage reaction is positive in ADAM reflecting that ADAM tends to stabilize the unemployment rate via the price of labour. In the SVAR, the real wage effect is more ambiguous and difficult to interpret. Another point is that in

17. We tried to model ADAM with no restrictions on the wage equation and simulate the temporary fiscal shock; this hardly changed our results.

the SVAR models, private consumption do not always increase as a response to an expansionary fiscal shock. This suggests that expenditure shocks are often tax-financed or that consumers are partly Richardian.

Shedding light on the crowding out process is important, and it may be of interest to pursue some of the differences between ADAM and the SVAR. This could be done by reformulating the SVAR in order to focus on, e.g., a model which explicitly takes cointegration or regime switching behaviour into account, or a model which focuses on other variables that are also essential in ADAM; for instance the market share of Danish exports and a differently defined real wage.

References

Auerbach, A. and Y. Gorodnichenko, 2012: Measuring the Output Responses to Fiscal Policy. *American Economic Journal: Economic Policy*, vol. 4(2), p. 1-27.

Blanchard, O. and P. Perotti, 2002: An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. *Quarterly Journal of Economics*, vol. 117 (4), p. 1329-1368.

Blanchard, O. J. and D. Quah, 1989: The dynamic effects of aggregated demand and supply disturbances. *The American Economic Review*, 79 (4), p. 655-673.

Efron, B. and R. J. Tibshirani, 1993: An Introduction to the Bootstrap, Chapman & Hall, New York.

Finansministeriet, 2014: Finansredegørelse 2014, Finansministeriet. (In Danish)

Hall, P., 1992: The Bootstrap and Edgeworth Expansion. Springer, New York. Hamilton, J., 1994: Time Series Analysis. Princeton University Press, Princeton, NJ.

Heppke-Falk, K. H., J. Tenhofen and G.B. Wolf, 2006: The Macroeconomic Effects of Exogenous Fiscal Policy Shocks in Germany: a Disaggregated SVAR Analysis. Deutsche Bundesbank. Discussion Paper Series 1: Economic Studies, No 41/2006.

Ilzetzki, E., E. Mendoza and C. Vegh, 2010: How Big (Small) are Fiscal Multipliers? NBER Working Papers, no. 16479, National Bureau of Economic Research.

Juselius, K., 2006: The Cointegrated VAR Model, Methodology and Applications, Oxford University Press.

Knudsen, D. and N. Gustafsson, 2013: Rapport om ADAMs tilpasningstid, Model group paper, Statistics Denmark. (In Danish)

Lütkepohl, H., 2006: New Introduction to Multiple Time Series Analysis, Springer, New York.

Pfaff, B., 2008: VAR, SVAR and SVEC Models: Implementation Within R Package vars, *Journal of Statistical Software*.

Pedersen, J., 2012: Fiscal policy in macroeconomic models, Danmarks Nationalbank, *Monetary Review*, 3rd Quarter 2012, Part 2.

Perotti, R., 2005: Estimating the Effects of Fiscal Policy in OECD Countries. CEPR Discussion Paper No. 4842.

Philip, L., 2003: The Cyclical Behaviour of Fiscal Policy: Evidence from the OECD. *Journal of Public Economics*, vol. 87, p. 2661-2675.

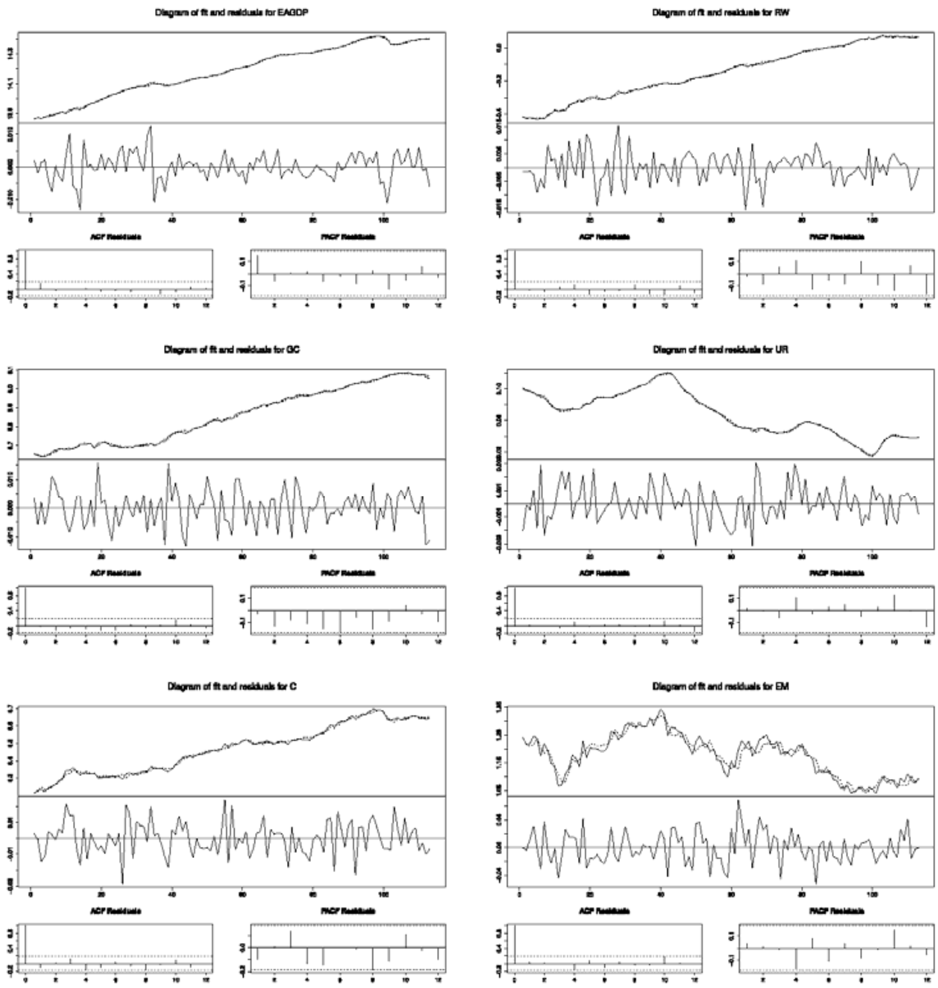
Phillips, P. C. B., 1998: Impulse Response and Forecast Error Variance Asymptotics in Nonstationary VARs, *Journal of Econometrics*, 83, 21–56.

Ravn, S. H. and M. Spange, 2014: The effects of fiscal policy in a small open economy with a fixed exchange rate: The case of Denmark, *Open Economies Review*, vol. 25(3), p. 451-476.

Ravnik, R. and I. Zilic, 2010: The use of SVAR analysis in determining fiscal policy shocks in Croatia, *Journal of Financial Theory and Practice*, 35 (1), p. 25-58.

Statistics Denmark, 2012: ADAM: A Model of the Danish Economy, Statistics Denmark.

10. Appendix A



Notes: ACF is short for autocorrelation function. PCAF is short for partial autocorrelation function. The upper and lower part of each subfigure are the fit and residual of each estimated equation in the SVAR.

Figure 5: Residual of the SVAR equations

11. Appendix B

Table 1: Augmented Dickey-Fuller tests.

Variable	Deterministic Terms	Lags	Test Value	Critical Value (5 percent level)
Ratio export/imports	Constant	1	-1.37	-2.88
Δ Ratio export/imports	Constant	1	-8.6	-2.88
Unemployment	Constant	4	-1.1	-2.88
Δ Unemployment	Constant	1	-3.36	-2.88
Log Private Consumption	Constant, Trend	1	-2.31	-3.43
Δ *Log* Private Consumption	Constant	1	-7.54	-2.88
Log Government	Constant, Trend	1	-1.29	-3.43
Δ *Log* Government	Constant	1	-6.69	-2.88
Log Real wage	Constant, Trend	1	-1.77	-3.43
Δ *Log* Real wage	Constant	1	-7.11	-2.88
Log US GDP	Constant, Trend	2	-1.38	-3.43
Δ *Log* US GDP	Constant	1	-4.09	-2.88
Log Euro area GDP	Constant, Trend	1	-1.72	-3.43
Δ *Log* Euro area GDP	Constant	1	-4.61	-2.88

Notes: The critical values are from Hamilton (1994), appendix B. The number of lags in the ADF-test are determined by the Bayesian information criterion.

Table 2: Serial correlation tests.

LMF(1)/LMF(4)	Lag X-vector: 0	Lag X-vector: 1	LM(1)/LM(4)	Lag X-vector: 0	Lag X-vector: 1
Lag Y-vector: 1	0.00/0.00	0.00/0.00	Lag Y-vector: 1	0.00/0.00	0.00/0.00
Lag Y-vector: 2	0.00/0.14	0.01/0.24	Lag Y-vector: 2	0.00/0.01	0.00/0.02
Lag Y-vector: 3	0.13/0.46	0.48/0.37	Lag Y-vector: 3	0.02/0.03	0.17/0.01
Lag Y-vector: 4	0.04/0.07	0.29/0.35	Lag Y-vector: 4	0.00/0.00	0.04/0.00

Notes: The numbers reported are probabilities of rejecting the zero hypothesis of no serial correlation.

Table 3: ARCH– and Jarque-Bera tests.

Equation residual	ARCH-test (1)	ARCH-test (2)	JB-Test (1)	JB-Test (2)
EAGDP	0.11	0.00	0.00	0.04
RW	0.05	0.04	0.94	0.59
GC	0.33	0.31	0.03	0.83
UR	0.70	0.54	0.46	0.59
C	0.68	0.48	0.43	0.97
EM	0.76	0.49	0.46	0.83
EAGDP	0.11	0.00	0.00	0.04
Multivariate:	0.3865	0.4236	0.00	0.44

Notes: The numbers reported are probabilities of rejecting the zero hypothesis of homoscedastic errors and normality for the ARCH– and the JB-test, respectively. We note that the JB-test is based on a Cholesky decomposition of the variance-covariance matrix, which makes it sensitive to the ordering of the variables, see Pfaff (2008). In the ARCH-test, we used 12 and 5 lags in the single and multivariate test, respectively. The tests denoted by (1) and (2) concern the model with and without dummies.

12. Appendix C

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0(0.41) & 0 & 0 \\ 0 & 0 & 0.0209 & 1 & 0 & 0 \\ 0 & -0.3965 & 0.2461 & 0.8957 & 1 & 0 \\ -0.3913 & 1.0234 & -0.0257 & -1.7466 & 0.6051 & 1 \end{pmatrix} \begin{pmatrix} u^{EAGDP} \\ u^{RW} \\ u^{GC} \\ u^{UR} \\ u^{C} \\ u^{EM} \end{pmatrix} = \begin{pmatrix} \varepsilon^{E\ AGDP} \\ \varepsilon^{RW} \\ \varepsilon^{GC} \\ \varepsilon^{UR} \\ \varepsilon^{C} \\ \varepsilon^{EM} \end{pmatrix} \quad (14)$$

13. Appendix D

To estimate the elasticity of unemployment on government expenditure, we follow Lane (2003) and estimate the following equation by OLS:

$$\Delta \log(GC_t) = c_0 + c_3 \Delta UR_t + m_t$$

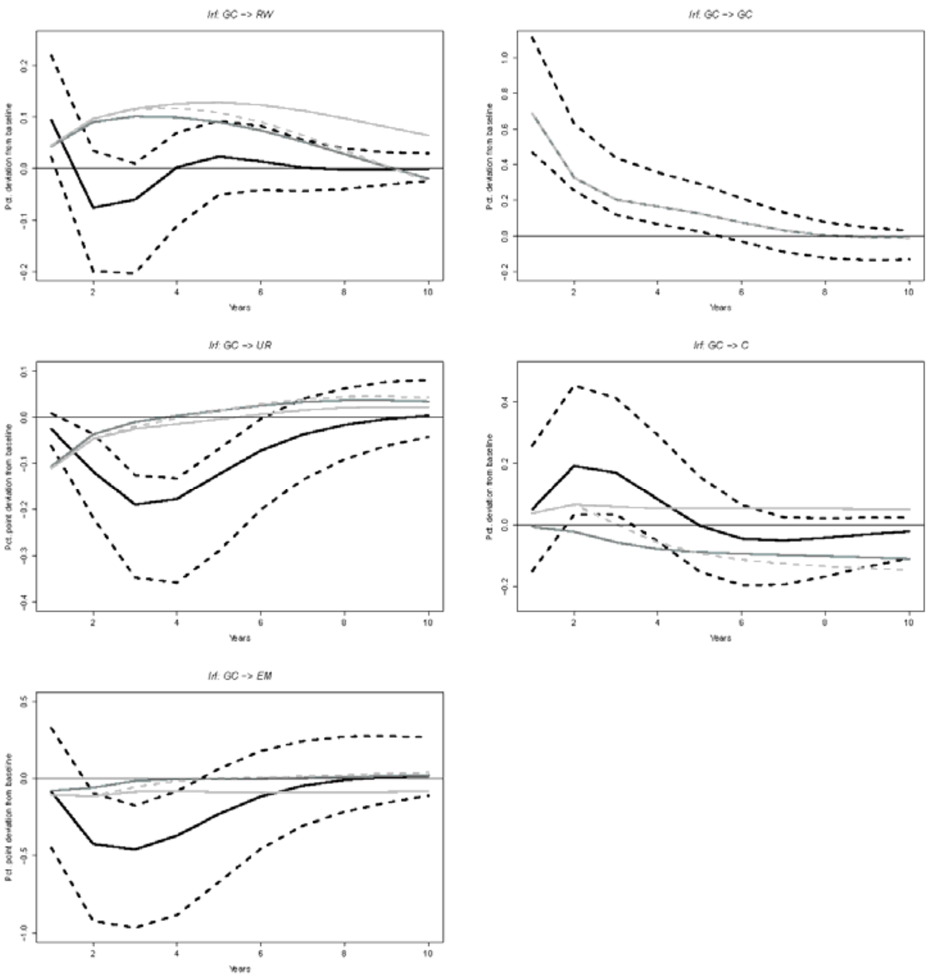
Here $\Delta\log(GC_t)$ is the change in the logarithm of government consumption, ΔUR_t is the change in the unemployment rate, m_t is the error term, c0 is the intercept, and c_3 is the elasticity of interest. We note that the OLS-estimator is inconsistent if the error term is correlated with the right hand side variable. The result is presented in the following table:

Table 4: Estimation of c_3

c_t	Estimate: -0.41	p-value: 0.136

The inference was calculated using a heteroskedaticity and autocorrelation corrected variance-covariance matrix (HAC-correction).

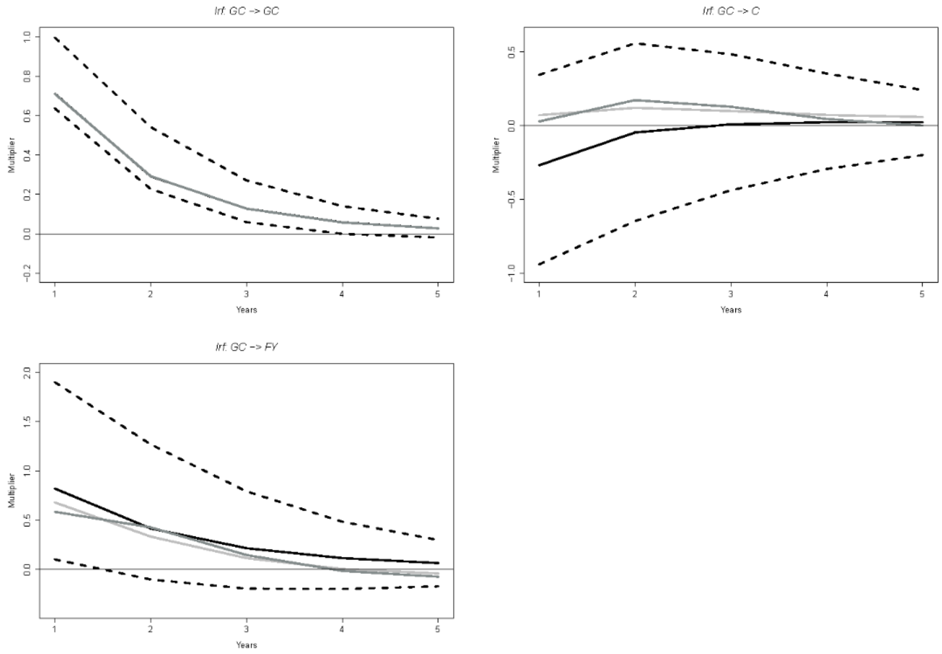
14. Appendix F



Notes: The black solid and dashed lines are impulse response functions and confidence intervals from the baseline SVAR. The solid grey line is an ADAM experiment with no financing. The grey dashed line is an ADAM experiment with financing starting in the shock year. The dark grey solid line is an ADAM experiment with financing starting two years after the shock year. The financing is set to keep the long term public debt to GDP ratio unchanged over the long term by adjustment of income taxes.

Figure 6: Comparison of a government consumption experiment: Public employment

15. Appendix G



Notes: The black solid and dashed lines are impulse response functions and confidence intervals from the SVAR in Ravn and Spange (2014). The dark grey line is an ADAM experiment where the shock to government consumption comes from government purchases of goods and services. The light grey line is an ADAM experiment where the shock to government consumption comes from public employment. In all subfigures, 1 is equal to 1 billion DKR. FY is real GDP. None of the ADAM experiments are financed.

Figure 7: Comparison: ADAM to Ravn and Spange (2014): Government consumption