Danmarks Statistik
MODELGRUPPEN
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Arbejdspapir*
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En sammenligning af ADAM og en SVAR

Resumé:

I papiret opstiller vi en strukturel vektorautoregressiv model, der omfatter følgende danske variable; realløn, offentligt forbrug, arbejdsløshed, privat forbrug og forholdet mellem eksport og import samt BNP i Euroområdet og USA. Modellen er inspireret af Hove og Spange (2014), men vi inkluderer lidt flere og lidt andre variable. Med den opstillede SVAR genererer vi de danske variables reaktion ved temporære stød til det offentlige og private forbrug og sammenholder med reaktionen i ADAM ved tilsvarende stød.

Vores resultater viser, at crowding out tiden for arbejdsløsheden i ADAM er kortere end i SVAR-modellen. ADAM og SVAR-modellens reaktion på stødene og tilpasning mod ligevægt minder om hinanden, men der er også forskelle. Den maksimale effekt fra stødene er størst i SVAR-modellen for alle variable med undtagelse af reallønnen, og den maksimale effekt på variablene indtræffer ikke samtidigt i modellerne. I ADAM er reallønnen og dens effekt modelleret til at have stor betydning for fortrængningsmekanismen, mens reallønnen i SVAR-analysen kun reagerer svagt og nogle gange kontraintuitivt.

For at undersøge robustheden af vores analyse har vi både prøvet at indlægge en skattereaktion, så den offentlige gæld ikke påvirkes på langt sigt, og prøvet at sammenligne ADAM med SVAR resultaterne i Hove og Spange (2014). Første års finanspolitiske BNP multiplikator ved stød til det offentlige forbrug er 1.15 i Hove og Spange (2014) og dem, vi finder, i ADAM er 0.96 og 0.82 for stød til hhv. det offentlige varekøb og den offentlige beskæftigelse. Sammenfattende fås, at ADAMs reaktion på temporære stød minder om reaktionen i en SVAR-model.

Vi takker Søren Hove Ravn and Morten Spange for udlevering af data vedr. deres resultater fra Hove og Spange (2014).

PAG
Nøgleord: SVAR, ADAM, Modelsammenligning.

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A Comparison of ADAM and a SVAR

Inspired by Hove and Spange (2014) we estimate a SVAR, which includes the following set of Danish variables; the real wage, government consumption, the unemployment rate, private consumption, the ratio of exports over imports, and GDP in the euroarea and in the US. With the estimated SVAR we can trace out impulse response functions, which we compare to ADAM multipliers. We compare the effects of two temporary demand shocks; a government and a private consumption shock. The comparison shows that the models react and reach equilibrium similarly, however, the crowding out of the unemployment effect is faster in ADAM. The peak effect on all variables except the real wage is largest in the SVAR, and also the timing of the peak effects differs between the models. In ADAM, the real wage has by construction a key role in the crowding out process, but in the SVAR, its importance seems questionable and it reacts less than or opposite to what one would expect. As robustness checks, we model the shocks in ADAM in different ways and we also compare ADAM to the results in Hove and Spange; none of the robustness checks changes our overall conclusion. The first year GDP fiscal multiplier of public consumption is 1.15 in Hove and Spange, and in ADAM we find multipliers of 0.96 and 0.82 for a shock to government purchases of goods and services and to public employment, respectively.

1 Introduction

The length of the crowding out process in Denmark is an ongoing topic for discussion. The mechanisms underlying the crowding out process can be more than one. Some of the more obvious candidates are via foreign trade, via a political reaction and (or) via a reaction in private consumption caused by Ricardian equivalence. Many studies have tried to quantify the crowding out process and the effect of different shocks on the Danish economy, and the attempts have applied different types of models, ranging from large-scale and highly structured simultaneous equation macroeconometric models (SEMs) to small-scale and less structured models. Within the class of SEMs we have the 2500-equation ADAM (Annual Danish Aggregated Model),[1] which is among the most used macromodels in Denmark.[2] ADAM provides a short and long run description of the Danish economy. Over the short term, ADAM is a traditional Keynesian model and over the long term it has neoclassical properties. Further, it neither has an endogenous fiscal reaction function nor forward looking expectations, and as the Danish economy is a small open economy with a fixed exchange rate vis-a-vis the euro, monetary policy is exogenous.

In the class of small-scale and less structured models we find the vector autoregressive (VAR) models. The VAR was introduced by Sims (1980), who argued that the exclusive restrictions in the SEMs are unreliable and that all economic variables are endogenous. One benefit of the VAR is that data can speak relatively freely and that the modeller needs only to impose a few assumptions prior to the estimation. However, the small-scale comes with a cost as it becomes easier to omit an important variable and as the connection to economic theory weakens. There are many differences between the VARs and SEMs. A typical VAR has 2-6 endogenous relations and a SEM can have thousands, which makes it possible to examine a wider range of analytical questions in a SEM. In opposition to the VAR, the relations in SEMs are often estimated separately often assuming that the independent variables are exogenous. Thus, they do not take all endogeneity issues into account, meaning that the properties of the estimator potentially fail. However, as the SEMs and VARs have different pros and cons, they should not necessarily be seen as rivals, but rather as complementary models, for, e.g. forecasting or economic policy making.

The intention of this paper is to compare a structural VAR (SVAR) to ADAM, which we will do in three steps: First, we estimate a SVAR on Danish data inspired by the approach of Hove and Spange (2014) and analyze the effect and crowding out time of different temporary economic shocks. Second, we shock the SVAR

[1] For more information on ADAM see Statistics Denmark (2012).

[2] Among the users of ADAM are The Ministry of Finance of Denmark and The Ministry of Economics and Interior of Denmark.

and ADAM similarly and compare the model responses. Third, we compare the SVAR-analysis presented in Hove and Spange to ADAM.

The SVAR is estimated on data from 1983 to 2011 and our interest lies in the relation between the following set of Danish variables; the real wage, the unemployment rate, government consumption, private consumption and a measure of the trade balance. To compare ADAM and the SVAR, we introduce two demand shocks, a government and a private consumption shock, and inspect whether the models react similarly with respect to the variables they have in common. We find that the crowding out mechanism is faster in ADAM than in the SVAR, and the crowding out difference increases if we finance the fiscal expansion via income taxes in ADAM.

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), who compares the effects of a temporary government consumption shock between the SVAR of Hove and Spange (2014) and Mona, a quarterly SEM of the Danish economy. Gomes et al. (2007) also finds that NiGEM,[3] the SEM of the NIESR,[4] react less than the SVAR presented in Alves et. al (2006) following a monetary policy shock. Oppositely, Els et al. (2002) finds a similar peak effect in a comparison of monetary policy shocks in a SVAR and the structural models; NiGEM and the ECB-AWM. [5] However, we note that the shocks are not modelled alike in Els et al. (2002), which might explain the similarity.

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 the analysis and of the robustness checks. In section 6 we compare the SVAR to ADAM, in section 7 we compare ADAM to the SVAR-results in Hove and Spange and section 8 concludes.

2 The model and the data

Our starting point is the following SVAR:

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

In equation (1) Y_t is a vector of endogenous variables and $\sum_{k=1}^{m} \alpha_k Y_{t-k}$ is a sum of lagged endogenous variables, Y_{t-k}, multiplied by a vector of coefficients, α_k.

[3]Short for National Institute Global Econometric Model.

[4]Short for National Institute of Economic and Social Research.

[5]Short for ECB area wide model.

$\sum_{j=0}^{l} \beta_j X_{t-j}$ is a sum of exogenous variables, X_{t-j}, multiplied by a vector of coefficients, β_j. Θ_0 is a vector of constants, Θ_1 contains the coefficients for the linear time trends, T, and Θ_2 contains the coefficients for the crisis dummy, EC, which is equal to 1 from the first quarter of 2008. u_t is an error term which can be written as $A_0^{-1}\epsilon_t$. A_0 is a matrix containing the parameters of the contemporaneous relation between the endogenous variables and ϵ_t are structural shocks. The vector of reduced form error terms should have an expected value of zero, a constant variance and be uncorrelated through time, i.e. $E(u_t) = 0$, $E(u_t u_\tau') = \Sigma_u$ for $\tau =$ t and $E(u_t u_\tau') = 0$ for $\tau \neq$ t.

In the model the vectors of endogenous and exogenous variables have the following content:

$$Y_t' = [EAGDP_t, RW_t, GC_t, UR_t, C_t, EM_t] \text{ and } X_t' = [USGDP_t]$$

In the endogenous vector, Y_t, $EAGDP_t$ is real GDP in the euro area, RW_t is the real wage, GC_t is government consumption, UR_t is the unemployment rate, C_t is private consumption and EM_t is the ratio of exports over imports. The last five variables in the endogenous vector are the Danish variables, which are all fully endogenous. The first variable in vector, Y_t, GDP in the euro area, is modelled as exogenous to the Danish variables so that no feedback is allowed from the Danish variables to the euro area.[6] In X_t we have the strictly exogenous variable, which is real GDP in the US, $USGDP_t$. Real GDP in the US is included to control for global shocks. All variables enter the system in log-levels except of the unemployment rate and the ratio of exports over imports, which are in logs.

We will argue that this set of variables is in line with a Keynesian model of a small open economy, as the variables capture the demand and supply side of the economy, as well as the effect from foreign economies. Government consumption, private consumption and exports over imports represent the demand side. The real wage and the unemployment rate represent the supply side, and the US and euro area are "the rest of the world".

In the analysis we will use seasonally adjusted quarterly data. All variables come from the Mona-database except for euro area 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 will inspect the variables for non-stationarity using an augmented Dickey-Fuller (ADF) test, where we add a number of lagged differences chosen by a Bayesian information criterion. Based on graphical inspection, we include constants in all level tests and time trends when appropriate. For

[6] As in Hove and Spange (2014), though, they use a weighted average of GDP in Germany and Sweden instead of euro area GDP.

the difference tests we include only constants. The results are reported in table 1. We note that. When the variables enter the ADF-test in levels the null cannot be rejected at a 5 percent significance level for any variable. When the variables enter the ADF-test in differences the null is rejected in all cases. Thus, we conclude that the variables in levels seem integrated of order one. We note that the ADF-test can be biased if a structural break is present in the data.

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
Δlog Private Consumption	Constant	1	-7.54	-2.88
Log Government Consumption	Constant, Trend	1	-1.29	-3.43
Δlog Government Consumption	Constant	1	-6.69	-2.88
Log Real wage	Constant, Trend	1	-1.77	-3.43
Δlog Real wage	Constant	1	-7.11	-2.88
Log US GDP	Constant, Trend	2	-1.38	-3.43
Δlog US GDP	Constant	1	-4.09	-2.88
Log Euro area GDP	Constant, Trend	1	-1.72	-3.43
Δlog Euro area GDP	Constant	1	-4.61	-2.88

Notes: The critical values are from Hamilton (1994), Appendix B.

Table 1: Augmented Dickey-Fuller tests

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. [7] The model is estimated on data from 1st quarter of 1983 to 4th quarter of 2011, so Denmark follows a hard currency 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. We apply both types of test, as the LMF-test is a small sample correction of the LM-test. [8] We test for serial correlation up to the 1st and 4th lag. The LMF-test suggests more than one set of lags for the endogenous and exogenous variables, as several p-values are above the 5 percent significance level, cf. table 2. On the other hand, the LM-test suggests 3 lags for all endogenous variables and up to 1 lag for the exogenous variables, as the p-values peak at these lags, 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, cf. table 3,

[7] See, e.g. Hove and Spange (2014), Blanchard and Perotti (2002) and Heppke-Falk et al. (2006).

[8] We justify this choice as 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 approximately 116.

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 2: Serial correlation tests

column 2. However, in the multivariate JB-test, normality is rejected, cf. table 3 column 4. An inspection of the JB-tests applied to each equation in the model indicates that the euro area GDP and the government consumption equation causes the rejection. Therefore, we choose to include two dummy variables[9] in the model and redo the regression. Now, the multivariate normality test cannot be rejected at a 5 percent significance level, cf. table (3), column (5). Furthermore, most of the LM-tests show no sign of autocorrelation[10], and a multivariate ARCH-test do not indicate any heteroskedasticity, cf. table (3), column (3). Finally, we once (again) inspect the residuals graphically; there is no sign of significant autocorrelation nor structural breaks, cf. figures in appendix A. We have also looked at the stability of the model using eigenvalues, and non of the eigenvalues are larger than one, cf. Appendix F, thus, the model seems stable. Shortly, we decide to continue with a model, which applies a set of deterministic terms including dummies, and uses 3 and up to 1 lag for the endogenous and exogenous variables, respectively.

3 Identification

To identify the causal relation between the - unobserved - structural shocks in ϵ and the endogenous variables, we have to identify the relation between structural and reduced form error terms. This may be done in more than one way; we will try two. First, we use a recursive identification strategy and, second, we try a structural one.

[9]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 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.

[10]The p-values: LMF(1) = 0.28, LMF(4) = 0.42, LM(1) = 0.07, LM(4)= 0.01.

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
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 without and with dummies.

Table 3: ARCH- and JB-tests

3.1 Recursive identification

The recursive strategy uses a Cholesky decomposition of the variance-covariance matrix of the reduced form residuals. This matrix, Σ_u, can be represented by $PP^{'}$, where P is a $6x6$ lower triangle matrix with standard deviations of the reduced form residuals in the main diagonal, covariances below and zeros above. Using $u_t = A_0^{-1}\epsilon_t$ the variance-covariance matrix of u_t can be written as; $\Sigma_u = A_0^{-1}\Sigma_\epsilon A_0^{-1}$. Setting $\Sigma_\epsilon = DD'$ where D is a diagonal matrix with the same main diagonal as P we get; $PP' = \Sigma_u = A_0^{-1}\Sigma_\epsilon A_0^{-1} = A_0^{-1}DD'A_0^{-1} \rightarrow A_0^{-1}D = P \rightarrow A_0 = DP^{-1}$, which means that $A_0 u_t = \epsilon_t$ becomes:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ -b_1 & 1 & 0 & 0 & 0 & 0 \\ -c_1 & -c_2 & 1 & 0 & 0 & 0 \\ -d_1 & -d_2 & -d_3 & 1 & 0 & 0 \\ -e_1 & -e_2 & -e_3 & -e_4 & 1 & 0 \\ -f_1 & -f_2 & -f_3 & -f_4 & -f_5 & 1 \end{pmatrix} \begin{pmatrix} u^{EAGDP} \\ u^{RW} \\ u^{GC} \\ u^{UR} \\ u^{C} \\ u^{EM} \end{pmatrix} = \begin{pmatrix} \epsilon^{EAGDP} \\ \epsilon^{RW} \\ \epsilon^{GC} \\ \epsilon^{UR} \\ \epsilon^{C} \\ \epsilon^{EM} \end{pmatrix} \qquad (2)$$

The system in equation (3) is just identified, and as P is lower triangle A_0 becomes lower triangle implying that a recursive structure is put on the contemporaneous relation of the variables. This means that all variables are affected within a quarter by a shock to the variable ordered first (in our case the ratio of exports over imports), but none of the other variables are affected within a quarter by a shock to the variable ordered last (in our case euroarea GDP). [11] The Cholesky identification

[11] We order the six endogenous variables as presented in the vector in the previous section, and we thereby assume; (i) Euro area GDP is ordered first and is unaffected by shocks to the five

strategy has its drawbacks, as it is sensitive to the ordering of the variables and as some of the imposed assumptions might be unrealistic. All in all, there are $5!$ possible orderings of the Danish variables, but we do not attempt to inspect more than one. Instead, we use a structural identification strategy, as an alternative.

3.2 Structural identification

This method is inspired by Hove and Spange. First we write the matrix equation $A_0 u_t = \epsilon_t$ as:

$$u^{EAGDP} = a_1 u^{RW} + a_2 u^{GC} + a_3 u^{UR} + a_4 u^{C} + a_5 u^{EM} + \epsilon^{EAGDP} \tag{3}$$

$$u^{RW} = b_1 u^{EAGDP} + b_2 u^{GC} + b_3 u^{UR} + b_4 u^{C} + b_5 u^{EM} + \epsilon^{RW} \tag{4}$$

$$u^{GC} = c_1 u^{EAGDP} + c_2 u^{RW} + c_3 u^{UR} + c_4 u^{C} + c_5 u^{EM} + \epsilon^{GC} \tag{5}$$

$$u^{UR} = d_1 u^{EAGDP} + d_2 u^{RW} + d_3 u^{GC} + d_3 u^{C} + d_5 u^{EM} + \epsilon^{UR} \tag{6}$$

$$u^{C} = e_1 u^{EAGDP} + e_2 u^{RW} + e_3 u^{GC} + e_4 u^{UR} + e_5 u^{EM} + \epsilon^{C} \tag{7}$$

$$u^{EM} = f_1 u^{EAGDP} + f_2 u^{RW} + f_3 u^{GC} + f_4 u^{UR} + f_5 u^{C} + \epsilon^{EM} \tag{8}$$

To solve this system one must impose a set of restrictions. We start by assuming, that euro area GDP is unaffected by Danish shocks so that $a_1 = a_2 = a_3 = a_4 = a_5 = 0$. The real wage is assumed only to be affected by its own shock, as nominal wage and price formations are sticky, which means that $b_1 = b_2 = b_3 = b_4 = b_5 = 0$. Thus, this identification scheme rules out a contemporaneous impact from euro area GDP on the real wage in opposition to the recursive structure. 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 (in our case) the macro variables, (ii) the systematic, discretionary response of government consumption to the macro variables, and (iii) the random, discrete fiscal policy shocks. We follow Blanchard and Perotti (2002), Hove and Spange (2014) and others, and assume that government consumption does 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

Danish variables. (ii) Real wage formation is sticky and do not react immediately to shocks to the other variables except to euro area GDP. Thus, the real wage can be interpreted as the least endogenous Danish variable in the system. (iii) Government consumption reacts immediately to euro area GDP and real wage shocks, but not to shocks to the unemployment rate, private consumption or exports over imports. (iiii) The unemployment rate reacts within a quarter to shocks to all variables except private consumption and exports over imports. (iiiii) Private consumption reacts immediately to all variables except shocks to exports over imports. (iiiiii) Exports over imports is the most endogenous variable and reacts immediately to shocks to all the other variables.

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.[12] This assumption makes (i) irrelevant, and without fiscal shocks of type (i) and (ii), we can set $c_1 = c_2 = c_3 = c_4 = c_5 = 0$. However, in section 7 we make a robustness check, where we estimate the semi-elasticity, c_3, and include it in the identification.[13]

The unemployment rate is allowed to react directly to government consumption shocks, but not to the other variables so $d_1 = d_2 = d_4 = d_5 = 0$. The idea is that fiscal authorities can directly affect public employment and therefore total unemployment, but the effects of other macro variables on the unemployment rate are more indirect, as it may take more than a quarter for a firm to hire workers following, e.g. a rise in private consumption. Private consumption is assumed to be unaffected by shocks to euro area GDP and to exports over imports, but is allowed to react immediately to shocks to the other variables, so that $e_1 = e_5 = 0$. Finally, exports over imports is expected to respond to all other variables within a quarter, which makes it the most endogenous variable in the model, as in the case of the recursive structure. Implementing all restrictions, we can simplify equation $(4) - (9)$ to:

$$u^{EAGDP} = \epsilon^{EAGDP} \tag{9}$$

$$u^{RW} = \epsilon^{RW} \tag{10}$$

$$u^{GC} = \epsilon^{GC} \tag{11}$$

$$u^{UR} = d_3 u^{GC} + \epsilon^{UR} \tag{12}$$

$$u^{C} = e_2 u^{RW} + e_3 u^{GC} + e_4 u^{UR} + \epsilon^{C} \tag{13}$$

$$u^{EM} = f_1 u^{EAGDP} + f_2 u^{RW} + f_3 u^{GC} + f_4 u^{UR} + f_5 u^{C} + \epsilon^{EM} \tag{14}$$

The remaining coefficients can be estimated using the reduced form residuals. To estimate (13), we use ϵ^{GC} as an instrument for u^{GC}, and obtain the residual u^{UR}. We then estimate (14), by regressing u^C on u^{RW}, u^{GC} and the residual determined by (13), which by assumption and construction is uncorrelated with u^{GC}. Equation (15) is estimated like (14), but we also include the residual from regression (14) as an instrument for u^C.

The estimated coefficients are available in appendix B. Now, we have identified all coefficients in $(10) - (15)$ and are able to calculate the effects of shocks to the SVAR model, or rather to the two SVAR models; one identified recursively and

[12]See, e.g. Hove and Spange or Ravnik and Zilic (2010).

[13]See appendix C.

one identified structurally.

4 Results

The resulting effects of shocks to the SVAR are shown in figure 1 and the graphs display both the results where the recursive identification is used, the blue solid line, and the result of using the structural identification, the black solid line. All shocks are temporary. They occur in the first quarter of the calculation period, and they come in size of one percent or percentage point. Hall (1992)s 95 percentile bootstrapped confidence intervals, CIs,[14] based on 5000 replications are included as a metric for the statistical significance. The red dotted CIs belong to the structurally identified model and the green ones to the recursive model. In the figure, each row presents the response of all Danish variables following a shock to one of the five Danish variables.

Real wage shock, figure 1, row 1: A positive real wage shock initially increases consumption and decreases exports over imports, but the effect disappears quickly. The unemployment rate increases, reaches a maximum after 2 years and is approximately back to zero after 7 years. We expect the rise in unemployment to happen, because a higher real wages deteriorates Danish competitiveness and reduces the demand for Danish goods, and because higher real wages make firms substitute away from labour towards capital.

Government consumption, figure 1, row 2: A government consumption shock decreases private consumption. After a few quarters the effects reverse and consumption rises while exports over imports starts to fall. The initial response of consumption suggests Ricardian behaviour of consumers as found by Hove and Spange, however, in our SVAR the effect becomes positive after a few quarters. We will return to this effect on private consumption in the following section on robustness checks. The unemployment rate falls initially and the impact from the government consumption shock peaks after three years. After approximately 5 years the government consumption effect is no longer significant, and the multiplier approaches zero seven years after the shock. The real wage increases a little during the first quarter, but this effect disappears after 2-3 quarters.

Unemployment shock, figure 1, row 3: A positive unemployment shock has a significant and puzzling positive short term effect on the real wage, but this effect disappears after 1.5 year. For the remaining variables the confidence intervals are quite wide, and therefore we abstain from commenting.

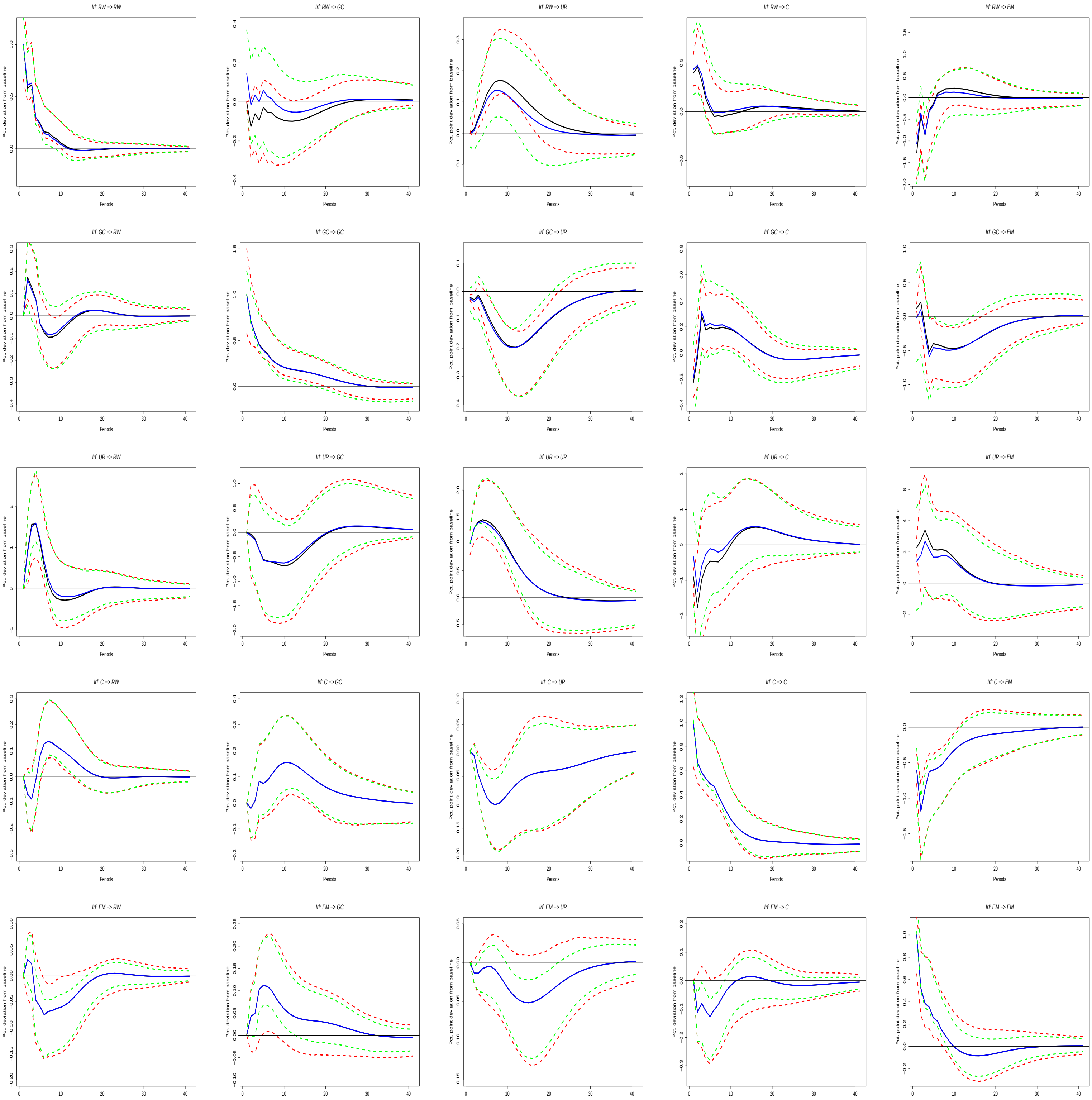
Private consumption shock, figure 1, row 4: A positive consumption shock

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

initially decreases exports over imports and we interpret this to reflect a rise in imports, as exports are expected to remain unchanged initially. The unemployment rate falls significantly, the fall reaches a maximum after approximately 2 years and slowly converges back toward the baseline. The reaction of government consumption is positive, but insignificant.

Exports over imports shock, figure 1, row 5: A positive shock to exports over imports can be interpreted in different ways. We may see it as an improvement in Danish competitiveness, which stimulates exports and reduces import. The Danish unemployment rate decreases as economic activity increases and the fall in real wages seems contra-intuitive.

All in all, the impulse response functions based on the different identification strategies do not differ much, which is not necessarily surprising, as the coefficient matrix of our structural identification approach almost has a lower triangle form.



Notes: The black and blue solid lines are impulse response functions from the structural and the recursive identification, respectively. The red and green dotted lines are 95 percent confidence intervals, which belongs to the structural and the recursive identification.

Figure 1: Impulse response functions

5 Robustness checks

In this section we present a robustness analysis, which consists of 5 separate checks. To stay focused we investigate only the government consumption shock and we concentrate on the impulse response functions of the structurally identified model, which serves as the baseline model. For the robustness checks we do not show confidence intervals.

Figure 2 show the effects of shocks to government consumption and each colored line represents the original model with a new feature. The black line is the original model presented in the previous section using the structural identification. The purple line is a model where we allow government consumption to react immediately to the unemployment rate. We have estimated the semi-elasticity, c_3, to -0.41, which suggests that government consumption was procyclically in the period of interest. We note that the estimate is significant on a 10 percent level and is based on a very simple estimation approach.

The green line represents a model, in which real GDP replaces the unemployment rate. The blue line represents a model estimated on a sample where we have excluded the crisis period, and the brown line represents a model with 4 and 2 lags of the endogenous and exogenous variables, respectively. As a final check we estimate our baseline model in first differences. In general, these models seem to react similarly to a government consumption shock. However, a few things are worth mentioning.

For instance, we note that allowing government consumption to react to the unemployment rate within a quarter does not make much difference, as the impulse response functions are hard to differentiate in the figures. For the model where we replace the unemployment rate by GDP, 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 findings of impact and cumulative multipliers around 1.3 in Hove and Spange, but higher than the multipliers estimated in Ilzetzki et al. (2011). Ilzetzki et al. 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 our cumulative multipliers.

If we exclude the crisis period after 2007 from the sample, it seems that consumers behave more Ricardian-like, as the effect on private consumption stays

[15] We have calculated the cumulative multiplier over a 25 quarter time horizon. However, using a 40 quarter horizon would not change the result much. The impact multiplier is calculated as: $\frac{\Delta GDP_1}{\Delta GC_1}$ and the cumulative multiplier as: $\frac{\sum_{t=1}^{25} \Delta GDP_t}{\sum_{t=1}^{25} \Delta GC_t}$ (Ilzetzki et al. (2011)), recall, that we shock in the first quarter of the sample. ΔX_t refers to the deviation of X_t from baseline in period t.

negative for a longer period following a government consumption shock. 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 it is worth considering that the effect on private consumption from government consumption can be regime dependent as found in Auerbach and Gorodnichenko (2012) for the US economy.

Concerning the model with extra lags, we just note that the impulse response functions become more volatile. As a final robustness check, we estimate our baseline model with the variables in first differences and simulate a government and a private consumption shock. The figures of the impulse response functions are shown in appendix D. The responses initially display the same pattern as in our primary results, however, the response functions are very volatile and they have wide CIs, which makes them difficult to interpret. It may be noted that a temporary shock to a model in differences produces a permanent shock to the levels, and therefore only the impact multiplier from the difference model can be compared between the level and the first difference model.

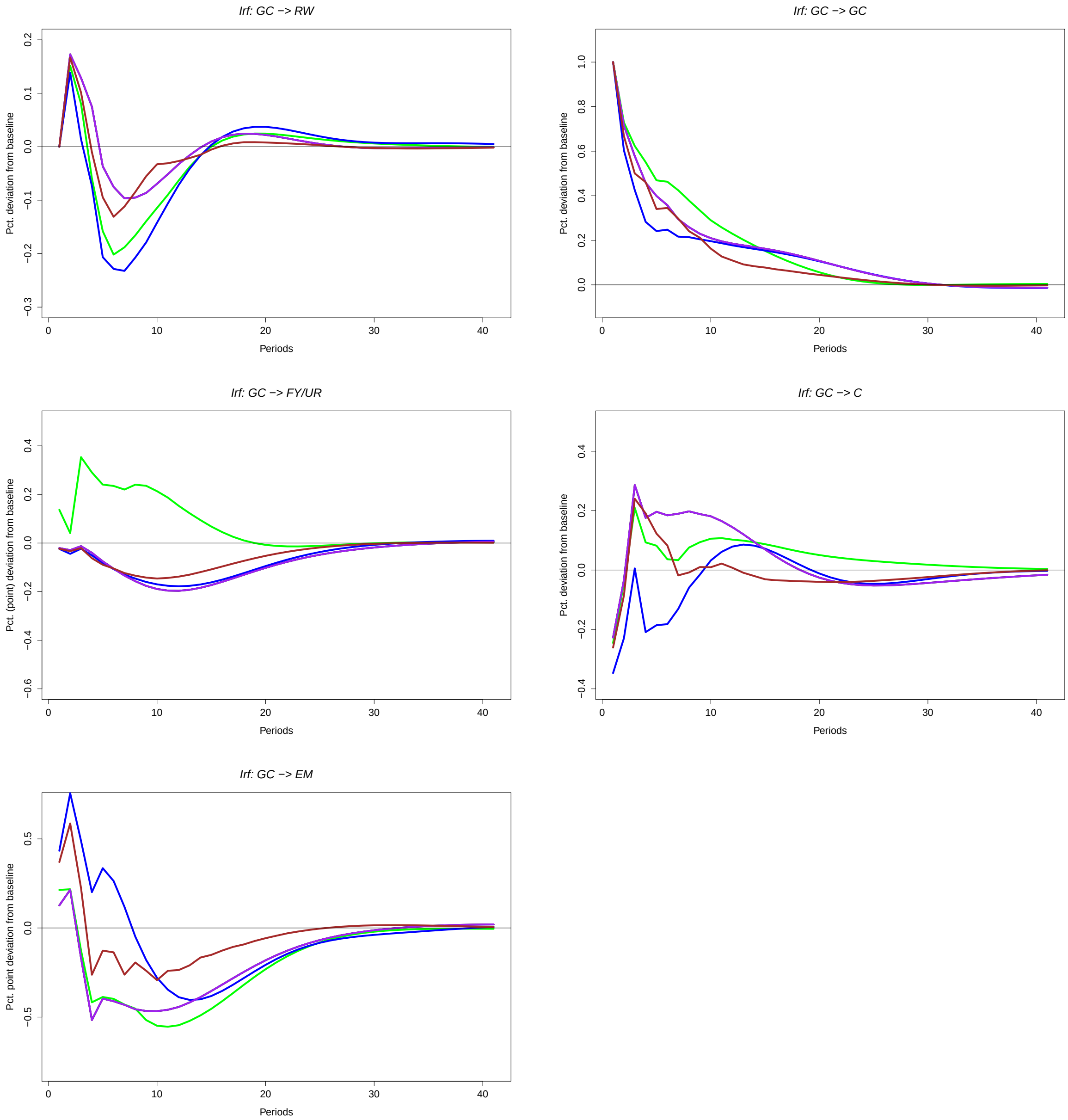
6 Comparison of ADAM and the SVAR

In this section, we compare the baseline SVAR model to ADAM over a ten year period following a shock. We focus on two demand shocks; a government and a private consumption shock. These shocks are convenient as they are standard experiments and easy to perform in ADAM without imposing too many extra assumptions.

Since government consumption is endogenous in the SVAR, and because ADAM does not have a fiscal reaction function, we have to take a stance upon how to formulate the shock to government consumption and decide whether the shock should be financed. In the SVAR, we do not know if the reaction of government consumption is financed, so we face the risk of comparing multipliers which are not comparable. To address this issue, we compare the SVAR results to more than one ADAM experiment. First we model ADAM as simple as possible, and afterwards we include an income tax reaction so that the public debt is unaffected over the long run.

As the SVAR runs on quarterly data, and as ADAM is an annual model, we calculate the annual average of the impulse response multipliers from the SVAR and compare the models in annual terms. In all experiments with government consumption shocks, we take the SVAR-calculated response of government consumption and insert it in ADAMs government consumption equation.

In ADAM, a government consumption shock can come from more than one source, as government consumption is a function of public employment, govern-



Notes: The purple line model in which government consumption automatically reacts to the unemployment rate in the first quarter. The blue line is model excluding the crisis from the sample. The brown line is model from section 5 with 4 and 2 lags of the endogenous and exogenous variables, respectively. The black line is the model from section 4.2 identified using the structural identification. No confidence intervals are provided. FY is real GDP

Figure 2: Robustness analysis; government consumption

ment purchases of goods and services and government reinvestments. The latter component is rather small, and we ignore it. However, there is a difference between shocking consumption via public employment or via government purchases of goods and services. When we shock the former, we make a combined shock as an increase in public employment automatically increases government consumption of goods and services. On the other hand, a shock to government consumption of goods and services has no effect on public employment. Therefore, we use two types of government consumption experiments in ADAM; one where the increase in government consumption comes from employment and one where the rise comes from purchases of goods and services. We will compare both of them to the SVAR.

6.1 Government consumption; public employment shock

First, we compare a government consumption shock in the SVAR to a public employment shock in ADAM. The results are shown in figure 3, where the black and red lines are the SVAR impulse responses and confidence intervals. The green and purple lines are the ADAM experiment, where the increase in government consumption comes from a rise in public employment. The green line shows an ADAM experiment, where the increase in government employment is not financed, i.e. the public debt ratio is allowed to change in the long run. The purple line represents an ADAM experiment where the increase in government consumption is financed, so that the public debt ratio is balanced over 25-30 years. The financing comes from a temporary rise in income taxes, which are set to rise two years after the shock and return to the baseline ten years after that. As the change in public consumption is temporary there is no need for a permanent increase in taxes, which makes the question of financing less crucial.

The shock to government consumption initially increases the real wage in ADAM and the SVAR. The difference between the effect in the models becomes significant after two years, where the real wage response in ADAM is above the CIs of the SVAR. In the tax-financed experiment the impact on the real wage in ADAM contracts somewhat faster towards the baseline, which brings the real wage response closer to the moderate response in the SVAR.

The effect on the unemployment rate has the same sign in the SVAR and ADAM, but in the SVAR, the effect peaks after a couple of years while the effect in ADAM peaks in the first year. In ADAM, the unemployment effect is crowded out after approximate 5 years. 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 experiment, the crowding out of the unemployment rate is faster, as higher taxes reduce private consumption and aggregate demand. We note that the faster crowding out in ADAM is followed by some overshooting and the positive second round effect on

ADAMs unemployment rate.

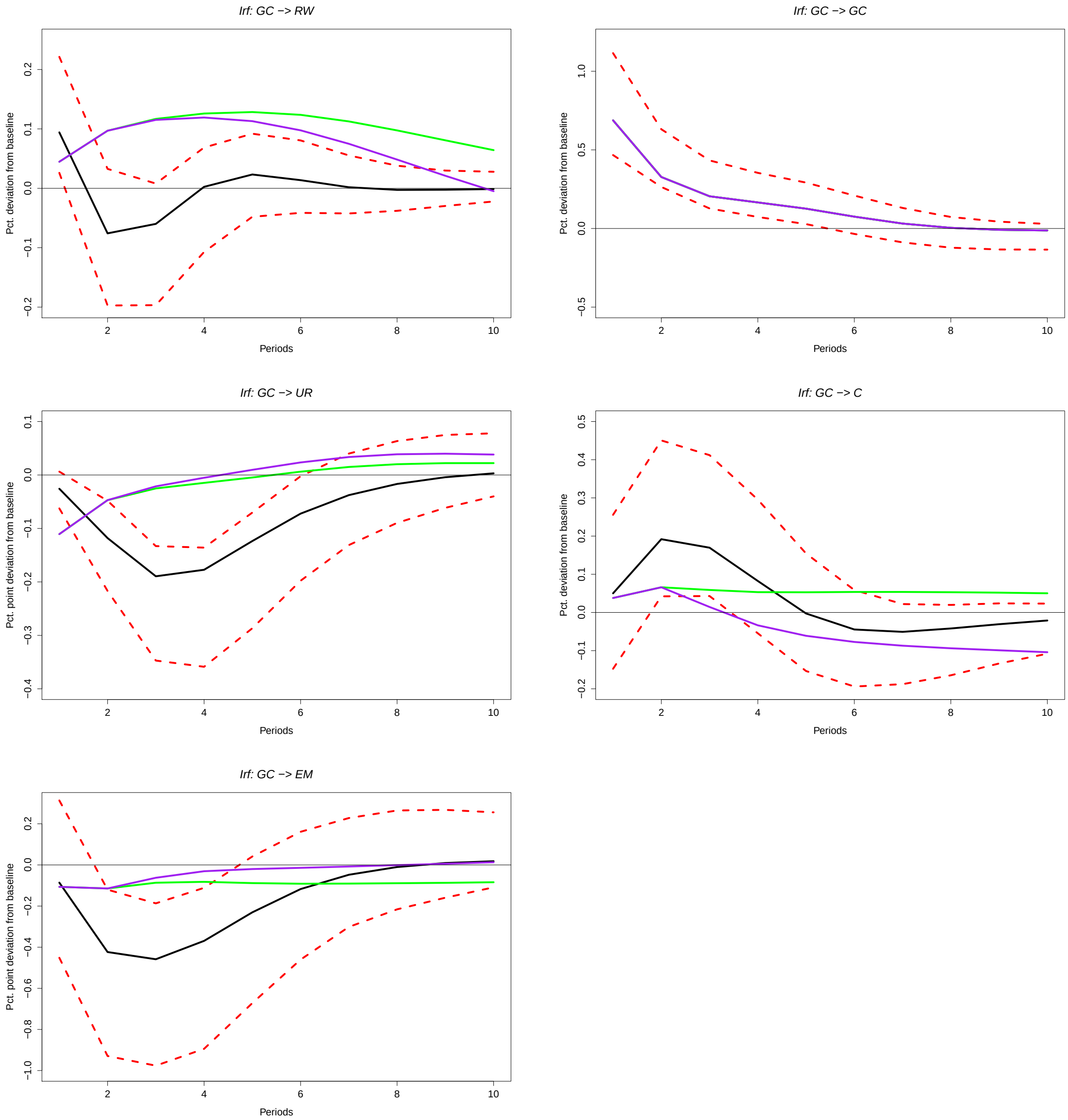
The initial effect on private consumption is positive in all experiments, but in the unfinanced ADAM experiment, the effect on private consumption hardly reduced during the entire period. In the financed experiment, the private consumption effect in ADAM lies within the CIs of the SVAR during most of the 10 year period. When it comes to the effect on the ratio of exports over imports, the models react similarly, though the maximal effect in the SVAR is larger than in ADAM. The effect peaks after three years in the SVAR, but already after one year in ADAM. In none of the experiments, ADAM seems to differ significantly from the SVAR during the entire period, and overall the SVAR and ADAM react similarly to the government consumption shock, however, the crowding out time in the SVAR seems longer than in ADAM. Moreover, the maximal effects on the variables seem larger in the SVAR with the exception of the real wage.

6.2 Government consumption; purchases of goods and services shock

Now, we compare the SVAR to ADAM, when the rise in government consumption comes from an increase in government purchases of goods and services. The results are shown in figure 4, where the colored lines represent the same type of experiment as described in the previous. Only the ADAM experiment has changed and the green line in figure 4, now shows the unfinanced increase in the government purchases of goods and services, while the purple line shows the tax financed increase.

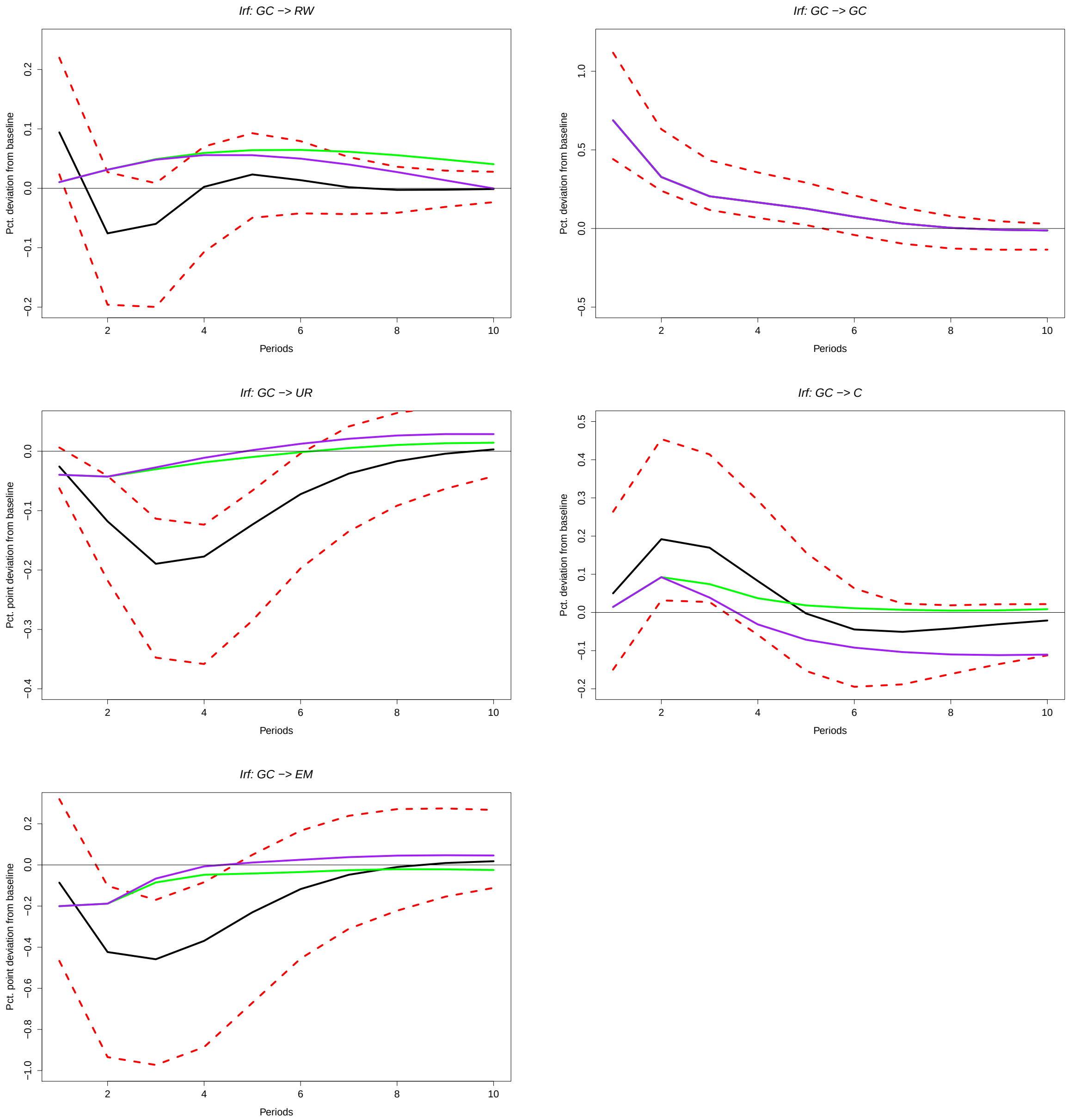
From the real wage graphs in figure 4 and 5, we see that the real wage in ADAM is affected less than when we shock government employment. The real wage effect in the unfinanced ADAM experiment is no longer statistically different from the SVAR with the exception of year 2 and 3. The response of the unemployment rate in ADAM is similar to that of the public employment experiment, and the crowding out time in ADAM remains faster than in the SVAR. However, it is only in the financed ADAM experiment, that the crowding out of the unemployment rate is significantly faster than the SVAR.

Overall, the selected variables in ADAM and the SVAR react with the same initial sign whether we shock the government consumption via government purchases of goods and services or via public employment in ADAM. However, the ADAM-result is a bit closer to the SVAR when we shock government purchases of goods and services especially wrt. the real wage.



Notes: The black and red dotted lines are impulse response functions and confidence intervals from the baseline SVAR. The green line is an ADAM experiment using the SVAR-based government consumption reaction. The purple line is an ADAM experiment with the SVAR-based government consumption reaction and a tax increase to keep the long term public debt ratio unchanged.

Figure 3: Comparison of a government consumption experiment; public employment



Notes: The black and red dotted lines are impulse response functions and confidence intervals from the SVAR. The green line is an ADAM experiment with the SVAR-based government consumption reaction. The purple line is an ADAM experiment with the SVAR-based government consumption reaction and a tax increase to keep the long term public debt ratio unchanged.

Figure 4: Comparison of a government consumption experiment; purchases of goods and services

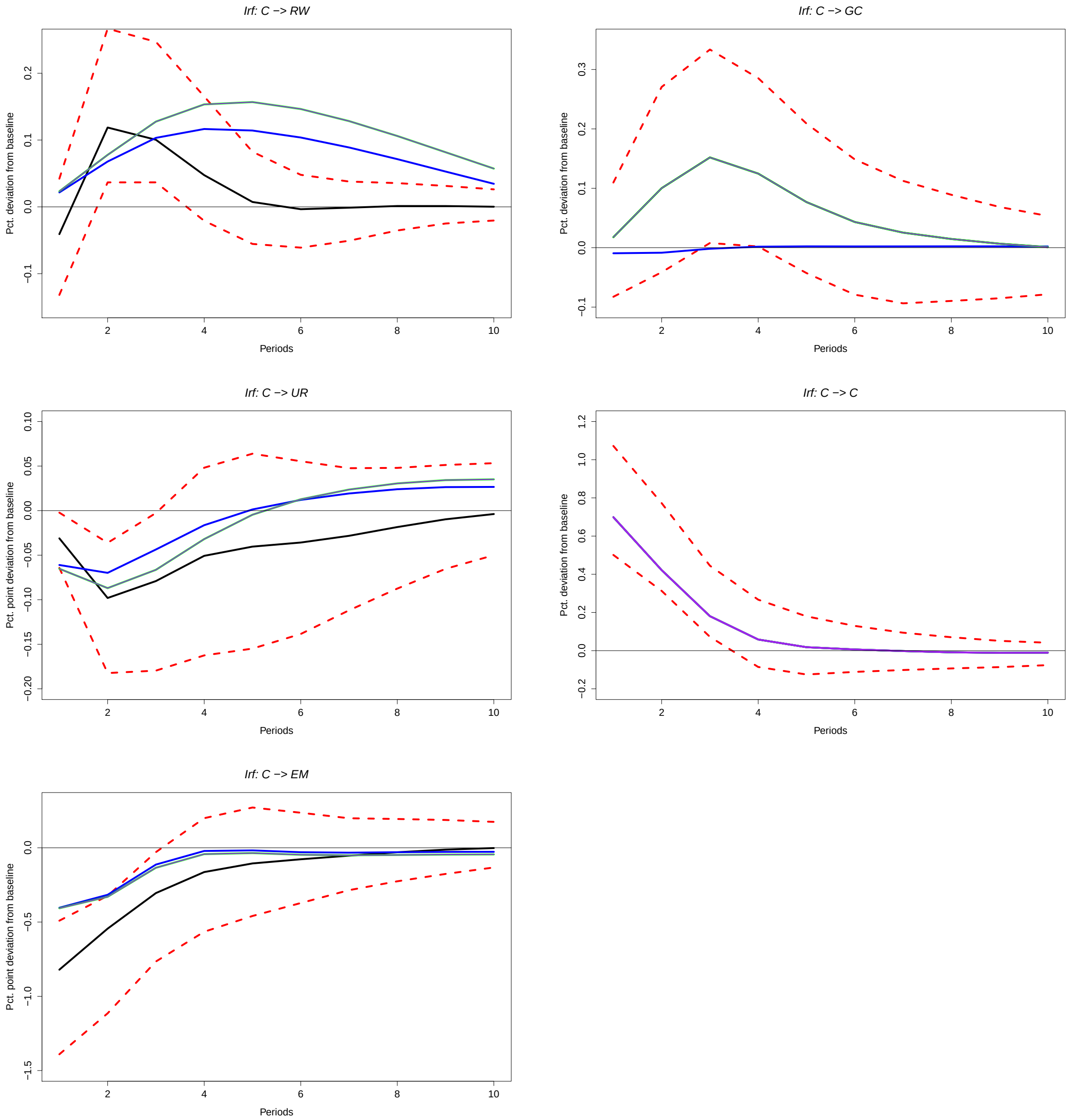
6.3 A private Consumption shock

In this section we compare a private consumption shock in ADAM and the SVAR. In order to do so, we need to translate the private consumption shock of the SVAR model to a shock in ADAM. We choose to mimic the SVAR-shock in ADAM by changing the adjustment term of the private consumption equation. However, when we shock private consumption in the SVAR model, all variables in the SVAR including public consumption will react as they are endogenous. In ADAM public consumption is exogenous, but if we see the SVAR-related reaction of public consumption as a policy reaction it should also be included in ADAM. Further, we should consider whether this change in public consumption is tax-financed, when we insert it in ADAM. Thus, there are three possibilities for setting up a private consumption shock in ADAM when we mimic the SVAR shock and the results of all three are given in figure 5. Again, the black and red dotted lines are the SVAR and its CI's. The blue line is a standard ADAM experiment with a one-off shock to the private consumption relation, the green line is the same experiment accompanied by an unfinanced government consumption reaction and the purple line is the experiment accompanied by a financed government consumption reaction.[16] We note that the difference between the green and the blue line is difficult to see, as the multipliers are rather similar.

The private consumption shock initially increases the real wage in the SVAR and in all three ADAM experiments. The real wage effect lasts longer in ADAM and the largest difference between ADAM and the SVAR concerns the experiments with a fiscal reaction. The unemployment rate falls in all experiments and the crowding out time in all ADAM experiments seem shorter than in the SVAR, however, the difference is insignificant. The effect on exports over imports do not differ significantly between the models, with the exception of the initial impact, where ADAM reacts less than the SVAR, as in the case of the government consumption shocks.

Finally, we shocked private consumption in ADAM in one period, and then allowed ADAM to reach equilibrium by itself both with and without a fiscal reaction; these figures can be found in appendix E. In this case, the differences between ADAM and the SVAR are small, which indicates that even in a simple experiment, ADAM can mimic the multipliers of the SVAR.

[16] In this case, the government consumption reaction comes from a change in public employment.



Notes: The black and red dotted lines are impulse response functions and confidence intervals from the SVAR. The green line is an ADAM experiment with the SVAR-based government consumption reaction. The purple line is an ADAM experiment with the SVAR-based government consumption reaction and a tax increase to keep the long term public debt ratio unchanged. The blue line is a pure private consumption experiment in ADAM.

Figure 5: Comparison of a private consumption experiment

6.4 Discussion

In this section we discuss why the effects from the shocks are different in ADAM and the SVAR. First of all, we have seen that the crowding out time is shorter in ADAM. One obvious reason could be that some of the crucial parameters in ADAM have been adjusted away from their estimated values in order to reduce the crowding out period. This is, e.g. the case for the wage relation. In ADAMs wage relation, the coefficient for inflation is restricted downwards and the coefficient for the unemployment rate is restricted upwards. The wage response in ADAM would be smaller, if the coefficients had not been restricted.

Moreover, the effects in ADAM including the effect on the unemployment rate are smaller than the corresponding effects in the SVAR, except in the case of the real wage. We are not sure about the proper explanation for this difference, but it is old news that the multipliers of the different models can differ a lot. We know that the multipliers of ADAM differ from those of the two other Danish SEMs, SMEC and Mona, and we could expect an even larger difference to a VAR model that is estimated in a different way. Notwithstanding, the difference between ADAM and the SVAR seems to weaken any a priori hypothesis that ADAM underestimates the crowding out process via Danish wage competitiveness. The stronger effect on unemployment in the SVAR comes with a stronger effect on domestic consumption and this would indicate that ADAM underestimates the pro-cyclical effect on domestic demand rather than the contra-cyclical response of exports. Furthermore, the difference in crowding out time between ADAM and the SVAR increases, when we finance the fiscal reaction via income taxes. As said, we are not sure about the interpretation of the SVAR results as the underlying economic structure is unknown. However, we can add that the macroeconometric model also has the smallest effects in the comparison of NiGEM and a SVAR presented in Gomes et al. (2007) and in the comparison of Mona and the Hove and Spange SVAR presented in Pedersen (2012) as mentioned.

Another issue is that the baseline of ADAM is a steady state growth path, while the baseline of the SVAR is stationary. This difference can be crucial for long term effects, but we have ignored it.

When we shock either private consumption in ADAM or the SVAR we do it via the error term / adjustment term in the private consumption equations. As we do not condition on the same set of variables in the SVAR and ADAM, it could be argued that the shocks are not the same, and therefore the finding of different results are not surprising.

We also have to note, that the models might include the same type of problems, which potentially makes them similar, but in the wrong way. Take, e.g. expectation formation. In ADAM expectations are adoptive and as the VAR is autoregressive it could be argued that the VAR also has backward looking expectations. Forward looking expectations might speed up the crowding out process in models, and therefore we potentially overestimates the crowding out time in both ADAM and the SVAR. Commonly we believe; the more backward looking a model is, the slower it becomes.

Lastly, we note that our SVAR approach is not based on a reduced rank estimation, which means that the our impulse response functions might be inconsistent at longer time horizons, cf. Phillips (1998). However, non-stationary variables in ADAMs multipliers potentially suffer of the same problem, as not all of ADAMs error-correction terms are cointegrated.

7 ADAM compared to Hove and Spange (2014)

In this section, we compare ADAM to the SVAR model of Hove and Spange. The Hove and Spange model includes the Danish variables; GDP (denoted FY), private consumption (denoted C) and government consumption (denoted GC). The setup of the comparison is as described in the previous sections, but we narrow the analysis to a time horizon of five years, and we only consider public consumption shocks.

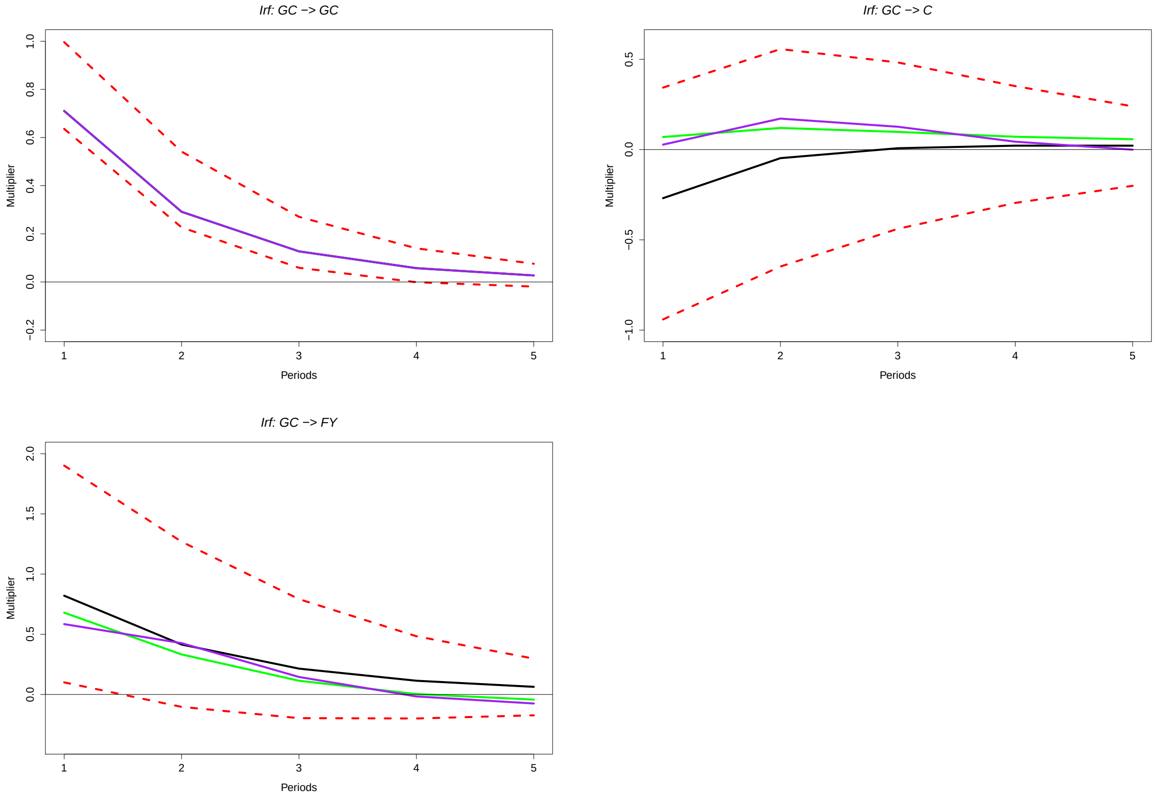
In figure 6, the solid black and red dotted lines are, respectively, the Hove and Spange SVAR response functions and CIs. The purple line represents an ADAMs experiment, where we shock government purchases of goods and services, and the green line represents an ADAM experiment where we shock public employment. Both shocks are unfinanced. The graphs can be interpreted as absolute multipliers, i.e. absolute deviations from baseline, which makes the fiscal multiplier on private consumption and GDP directly observable in the figure.

We note that the effect on total government consumption is identical in all experiments, as we again use the SVAR reaction in ADAM. The effect on private consumption in ADAM is not significantly different from the SVAR, however, the effect on private consumption in Hove and Spange is negative during the first three years, but positive in all years in the two ADAM experiments. We note that the private consumption effect in Hove and Spange is reported to change, from negative to almost solely positive, if Hove and Spange increase the number of lags in their model. So, they do not find a clear-cut response of private consumption to a government consumption shock.

The effect on GDP has the same sign in the SVAR and the ADAM experiments, but the effect in ADAM is a bit smaller. The first year multiplier in Hove and Spange is 1.15 versus 0.96 and 0.82 in ADAM when we shock public employment and government purchases of goods and services, respectively. This difference to the SVAR seems insignificant as the ADAM generated curves lie within the confidence interval of the SVAR.

As mentioned, Pedersen (2012) makes a similar comparison between the Hove and Spange SVAR and Mona. It differs from our comparison as Mona is in quarterly terms, but Pedersen´s result for Mona is similar to the results we find for

ADAM, as the GDP effect of public consumption is crowded out more quickly in Mona than in the SVAR.



Notes: The black and red dotted lines are impulse response functions and confidence intervals from the SVAR in Hove and Spange (2014). The purple line is an ADAM experiment where the shock to government consumption comes from government purchases of goods and services. The green 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

Figure 6: Comparison: ADAM to Hove and Spange (2014); government consumption

8 Conclusion

We have estimated a SVAR and compared the effect of temporary government and private consumption shocks with ADAM. The main conclusions are; (1) the variables in the SVAR and ADAM reacted with the same initial sign to the shocks in most cases, (2) ADAM seems to crowd out faster than the SVAR, though, the difference is not always significant, (3) supplementing the shocks to ADAM with an income tax reaction increases the similarity of the models for most variables except for the unemployment rate, and (4) the largest difference between ADAM and the SVAR concerns the effect on the real wage, which reacts far stronger in ADAM than in the SVAR.

As a robustness check we also compared ADAM to the SVAR in Hove and Spange (2014). In this comparison of a government consumption shock, the initial sign of the effect on private consumption differed, as the SVAR effect was negative. The effect on GDP was positive in both the SVAR and ADAM and the crowding out time of GDP was faster in ADAM than in the SVAR of Hove and Spange, although the difference was not significant.

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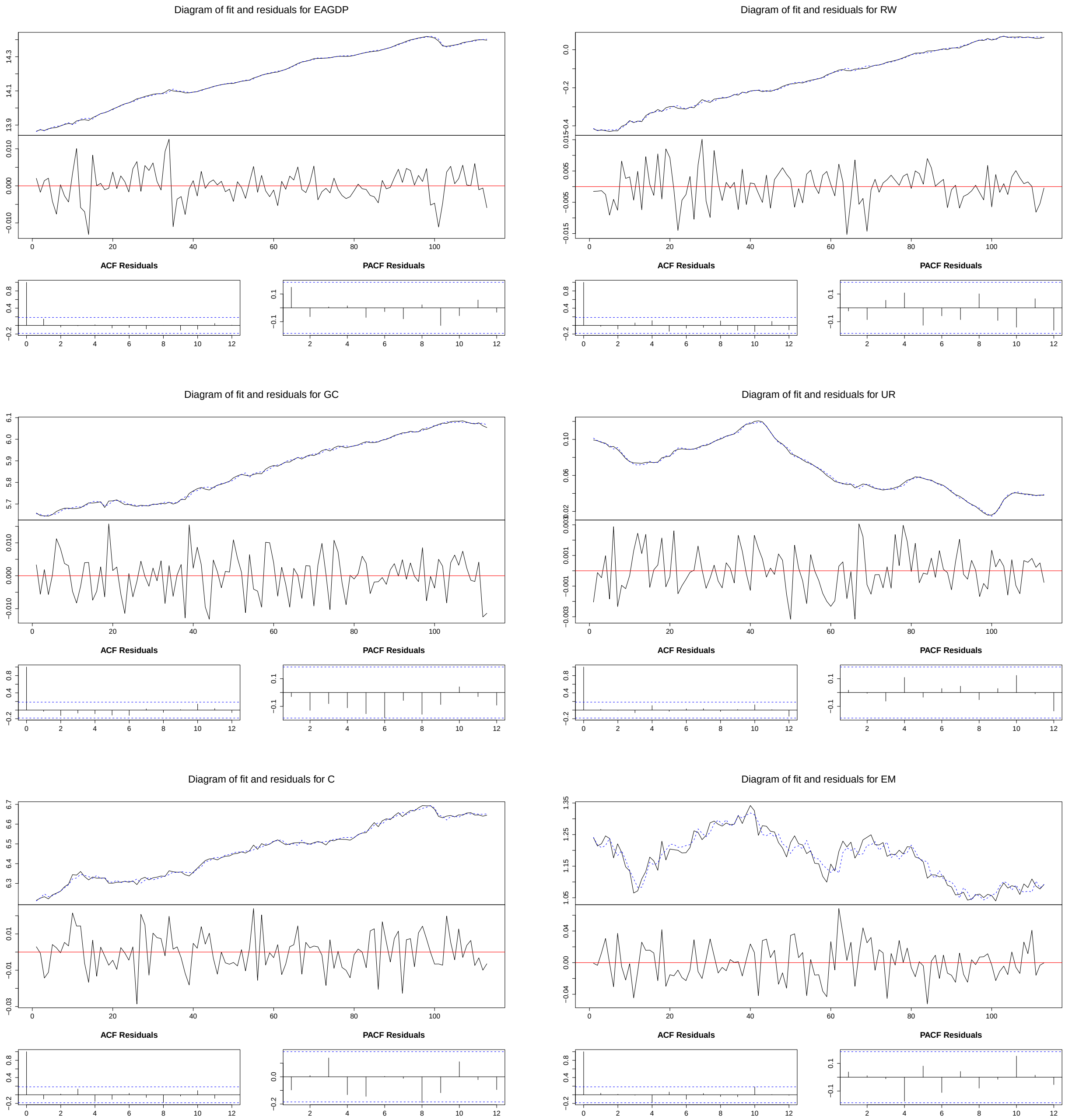
8.1 Appendix A



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 7: Residual of the SVAR equations

8.2 Appendix B

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0(0.41) & 0 & 0 \\ 0 & 0 & 0.0209 & 1 & 0 & 0 \\ 0 & -0.3965 & 0.2461 & 0.8957 & 1 & 0 \\ -0.3913 & 1.0234 & -0.0257 & -1.7466 & 0.6051 & 1 \end{pmatrix} \begin{pmatrix} u^{EAGDP} \\ u^{RW} \\ u^{GC} \\ u^{UR} \\ u^{C} \\ u^{EM} \end{pmatrix} = \begin{pmatrix} \epsilon^{EAGDP} \\ \epsilon^{RW} \\ \epsilon^{GC} \\ \epsilon^{UR} \\ \epsilon^{C} \\ \epsilon^{EM} \end{pmatrix} \quad (15)$$

Notes: The value in bracket is an estimate from the original variables (see appendix C). The values without a bracket are estimates from the residuals of the SVAR.

8.3 Appendix C

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

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

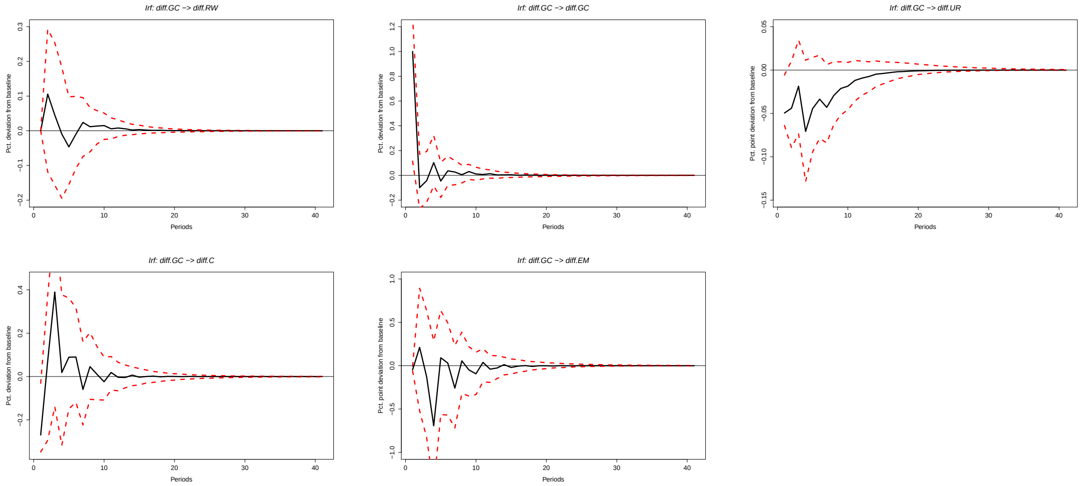
here $\Delta log(GC_t)$ is the change in the logarithm of government consumption, ΔUR_t is the change in the unemployment rate, m_t is the error term, c_0 is the intercept and c_3 is the elasticity of interest. We note that the OLS-estimator is inconsistent if the error term is correlated with the right hand side variable. The result is presented in the following table:

c_3	estimate: -0.41	p-value: 0.136

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

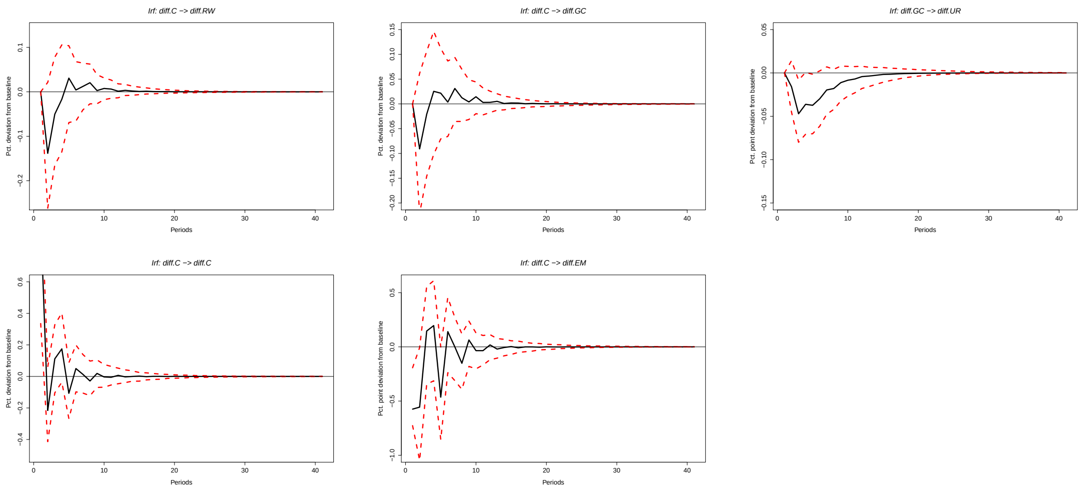
Table 4: Estimation of c_3

8.4 Appendix D



Notes: The black line is the impulse response function, and the red dotted lines are confidence intervals. The model is based on the structural identification.

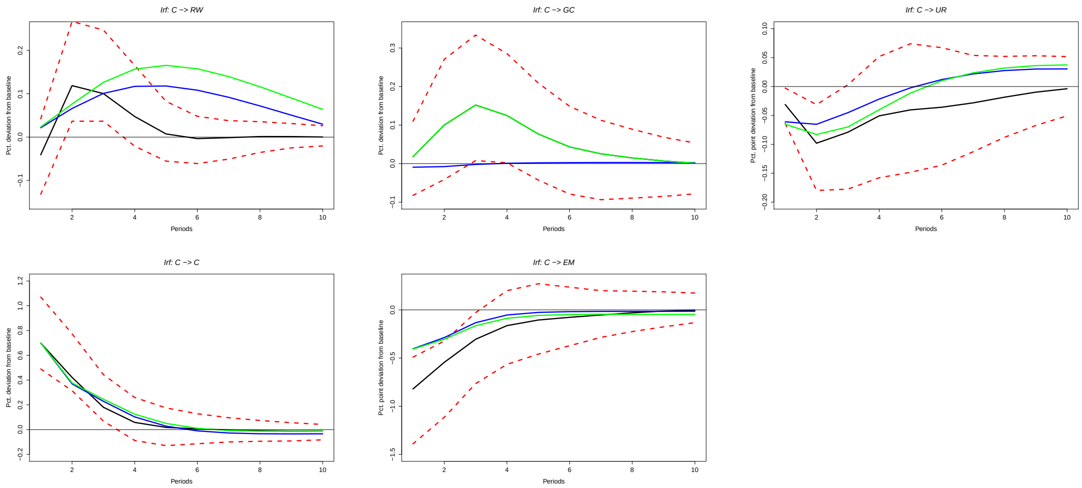
Figure 8: Robustness analysis; first difference model - government consumption.



Notes: The black line is the impulse response function, and the red dotted lines are confidence intervals. The model is based on the structural identification.

Figure 9: Robustness analysis; first difference model - private consumption.

8.5 Appendix E



Notes: The black and red dotted lines are impulse response functions and confidence intervals from the SVAR. The green line is an ADAM experiment with the SVAR-based government consumption reaction. The blue line is an ADAM experiment with the SVAR-based government consumption reaction and a tax increase to keep the long term public debt ratio unchanged.

Figure 10: Comparison; private consumption

8.6 Appendix F