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Resumé

Denne artikel undersøger effekterne af finanspolitik i Danmark siden indførelsen af fastkurspolitikken i 1982. Vi viser, at ekspansiv finanspolitik har en relativ stor indvirkning på den økonomiske aktivitet på helt kort sigt, idet den finanspolitiske multiplikator i vores foretrukne specifikation er på 1,3 i det første kvartal efter indgrebet. Danmarks faste valutakurs indebærer, at den nominelle rente forbliver uændret efter et ekspansivt finanspolitisk indgreb, hvilket skaber mulighed for, at indgrebet kan have en betydelig realøkonomisk virkning. På den anden side betyder dansk økonomis høje grad af åbenhed, at en substantiel andel af den finanspolitiske stimulans vil være rettet mod importerede varer. Resultaterne tyder på, at effekten af den "pengepolitiske akkomodering" er stærkere end "lækageeffekten". Vi finder desuden, at effekterne af ekspansiv finanspolitik er meget kortvarige i Danmark, idet effekten på det reale bruttonationalprodukt, BNP, bliver insignifikant efter ca. et år. Den finanspolitiske multiplikator er kun større end 1 i det første kvartal efter indgrebet, og falder til 0,6 efter et år. Vi viser endvidere, at den finanspolitiske multiplikator langt fra er konstant over tid. Mens multiplikatoren var under 1 i 1970'erne og 1980'erne, har den været over 1 siden omkring 1990, hvor Danmark har haft en troværdig fast valutakurs og sunde offentlige finanser.

The Effects of Fiscal Policy in a Small Open Economy with a Fixed Exchange Rate: The Case of Denmark*

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Abstract

We study the empirical effects of fiscal policy in Denmark since the adoption of a fixed exchange rate policy in 1982. We demonstrate that fiscal stimulus has a rather large impact on economic activity in the very short run, with a government spending multiplier of 1.3 on impact in our preferred specification. Denmark's fixed exchange rate implies that the nominal interest rate remains fixed after a fiscal expansion, facilitating a substantial impact of the fiscal stimulus on the real economy. On the other hand, the large degree of openness of the Danish economy means that a sizeable share of the fiscal stimulus will be directed towards imported goods. Our results suggest that the 'monetary accomodation channel' dominates the 'leakage effect'. We also find that the effects of fiscal stimulus are very short-lived in Denmark, with the effect on output becoming insignificant after around a year. The fiscal multiplier is above 1 only in the first quarter, and drops to 0.6 one year after the shock. We further demonstrate that the fiscal multiplier is far from constant over time. While the multiplier was below 1 in the 1970's and 1980's, it has been above 1 in the 1990's and the 2000's, when Denmark has had a credibly fixed exchange rate and sound public finances.

JEL classification: E32, E62, F41.

Keywords: Fiscal Policy, Fixed Exchange Rates, Structural VARs.

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1 Introduction

The macroeconomic effects of discretionary fiscal policy have been the subject of a longstanding, academic debate.[1] The present paper adds to this debate by presenting an empirical analysis of the effects of fiscal policy in Denmark. Since 1982, Denmark has been conducting a fixed exchange rate policy, with its currency, the Krone, pegged first to the German D-mark, and since 1999 to the euro. The Danish economy is characterized by a large degree of openness, with a ratio of exports to GDP around 50 % in recent years. Hence, the effects of fiscal policy in Denmark are interesting also from a theoretical point of view. A fixed exchange rate is traditionally believed to allow for relatively large effects of fiscal policy, as this implies that the nominal interest rate is held fixed; while it is likely to be raised under a floating exchange rate (see e.g. Corsetti *et al.* (2011), or the textbook Mundell-Fleming model). In particular, to the extent that prices and wages are sticky in the short run, no nominal adjustment can take place, so an increase in government spending is likely to have a large effect on output. At the same time, however, the large degree of openness implies that a relatively large share of fiscal stimulus is likely to be spent on foreign goods or services. This 'leakage' effect is likely to dampen the size of the fiscal multiplier (Beetsma and Giuliodori, 2011).

While the former effect has traditionally received more attention in the literature, the relative importance of these two opposite effects is ultimately an empirical question, which we seek to address in this paper. To this end, we employ a structural vector autoregressive (SVAR) model, and follow the identification strategy first described by Blanchard and Perotti (2002). As we are considering a country for which economic fluctuations abroad are very important, we augment the SVAR approach of Blanchard and Perotti to take into account business cycle movements in Denmark's most important trading partners; Germany and Sweden. We also control for global business cycle fluctuations, such as a global technology shock, by including US GDP as an exogenous variable in the model.

Our empirical results indicate that the fiscal multiplier in Denmark is relatively large in the short run. For the period 1983-2011, i.e. since the introduction of the currency peg, we find an estimated government spending multiplier of 1.3 on impact. However, we also find that the expansionary effects of government spending die out quickly. The multiplier is above 1 only in the first quarter, and is significantly greater than zero only during the first year in our baseline specification. The cumulative multiplier, which measures the accumulated increase in output relative to the accumulated increase in government spending during the first 20 quarters, is also 1.3; indicating that the effects of fiscal stimulus die out as the stimulus itself is removed. This suggests that the dynamic effects of government spending in Denmark are small.

The relatively large impact multiplier tends to suggest that in the short run, the interest rate effect is indeed more important than the leakage effect. After a while, the opposite

[1] We refer the reader to Coenen *et al.* (2010) or Hebous (2011) for extensive surveys on this literature.

seems to be the case. There are, however, other potential explanations for the extremely short-lived effects of fiscal stimulus in Denmark. As prices and wages start to adjust, the relative price of Danish goods and services will rise, inducing Danish as well as foreign consumers to substitute away from these. While this terms of trade-effect is present for all open economies, it is likely to be particularly important for a very small, open economy such as Denmark, as its products make up only a tiny fraction of the consumption basket of foreign consumers, and thus exert only a small effect on foreign inflation. As a result, the rise in domestic relative to foreign inflation is large. Moreover, given the large export share in the Danish economy, the resulting drop in exports is likely to outweigh the rise in domestic government spending. Finally, Denmark has very important automatic fiscal stabilizers. These tend to dampen the persistence of economic shocks, including shocks to government spending.

Our results are consistent with other recent, empirical findings. Ilzetzki *et al.* (2010) study a sample of 44 countries, and find a cumulative multiplier of around 1.5 in economies operating under fixed exchange rates, while the multiplier is much lower (and significantly so) in countries with floating exchange rate regimes. These authors furthermore find empirical support for the importance of the interest rate channel, as they report an increase in the nominal interest rate under flexible exchange rates. Corsetti *et al.* (2012) study the effects of fiscal policy in 17 OECD countries, and also find a significantly higher fiscal multiplier under fixed exchange rates. They find an estimated multiplier of 0.6 under fixed exchange rates, and around zero under floating rates. On the other hand, they find no direct evidence in favor of the interest rate effect. Beetsma and Giuliodori (2011) find a fiscal multiplier around 1.2 for a sample of 14 member countries of the European Union, although for the most open economies among these, including Denmark, the multiplier is found to be slightly below 1. This highlights the importance of the leakage effect, which has also been emphasized by Zhang and Zhang (2010). Nakamura and Steinsson (2011) estimate a fiscal multiplier of around 1.5 based on US data at the state and regional level. The idea is that each state represents a small, open economy with a fixed exchange rate relative to its neighbour states. What they report is the so-called *open economy relative multiplier*, which measures the change in output in one state relative to other states when government spending in that state is increased. As such, their result is not directly comparable to ours. Finally, Bergman and Hutchison (2010) study the effects of fiscal policy in Denmark in a setup related to ours, but with a sample from 1971-2000, and with specific focus on the effects of the Danish fiscal contraction in the mid-1980's. Our results are in general consistent with their findings, although some differences arise due to the use of different model specifications and different sample periods. It should be noted, however, that our results differ from those in the literature in one important aspect. We find that private consumption drops on impact in response to an increase in government spending.[2] This is different from most studies

[2] The reason why the fiscal multiplier can be larger than 1 even though private consumption drops is that we find a rise in private investment on impact, after which it becomes insignificant

following the approach of Blanchard and Perotti (2002), which tend to find an increase in private consumption. On the other hand, studies in the tradition of Ramey and Shapiro (1998) and Ramey (2011a) tend to find a drop in private consumption, more in line with our results.[3] However, we find the response of consumption to be significantly different from zero only on impact, after which the response is very close to zero.

A related, recent strand of the literature focuses on the effects of government spending when the zero lower bound on nominal interest rates is binding (see e.g. Christiano *et al.*, 2011). In that case, just as in a small open economy with a fixed exchange rate, the nominal interest rate does not move in response to a government spending shock. As a result, the short run real interest rate goes down due to the rise in inflation resulting from the fiscal stimulus. As argued by Nakamura and Steinsson (2011), however, the fiscal multiplier in a small open economy with a fixed exchange rate is substantially smaller than in an economy where the interest rate is at its zero lower bound. The reason is that under a fixed exchange rate, the initial rise in domestic inflation must eventually be followed by a drop in domestic (relative to foreign) inflation, so as to keep relative foreign and domestic prices constant in the long run. As a result, the long-term real interest rate is unaffected. At the zero lower bound, instead, this mechanism is not present, so the long-term real interest rate also drops. This stimulates current demand further, facilitating a very large government spending multiplier, as reported by Christiano *et al.* (2011), among others.

One of the key insights of the recent literature on fiscal policy is that the government spending multiplier is not constant, but differs substantially across different states of the economy, as well as over time (Favero *et al.*, 2011; Auerbach and Gorodnichenko, 2012). We corroborate this finding by studying how the fiscal multiplier in Denmark has evolved over time since 1971. We find that in the 1970's and 1980's, the impact multiplier was smaller than 1, while in the 1990's and the 2000's, the multiplier has been above 1. In the 1970's and 1980's, Denmark suffered from unsound public finances, and while the fixed exchange rate policy was adopted in 1982, a credible currency peg is not gained overnight. As a result, fiscal expansions were likely to be met by expectations of higher inflation and higher interest rates, resulting in a low spending multiplier. On the other hand, the latter two decades correspond to times of low and stable inflation, sound public finances, and a credibly fixed exchange rate, laying the ground for more effective fiscal policy. Interestingly, Billbie *et al.* (2008) reach the opposite conclusion for the US, as they document a drop in the fiscal multiplier over time. As for Denmark, however, they find that this result can (at least partly) be attributed to regime shifts in US monetary policy.

To shed additional light on the importance of fiscal policy in Denmark, we present historical decompositions of output fluctuations. The main and unsurprising result from this exercise is that the Danish business cycle is to a large extent driven by economic fluctuations abroad. In particular, and especially since the mid-1990's, the Danish business

[3] This literature focuses on anticipation effects by assuming that agents react to fiscal policy shocks when they are announced, rather than when they are implemented.

cycle has been under heavy influence from global fluctuations (as measured by US GDP). On the other hand, shocks to government spending account for a small fraction of output fluctuations. Our decomposition suggests that Danish policymakers have not always been successful in conducting a countercyclical fiscal policy that might alleviate the fluctuations coming from abroad. For example, fiscal policymakers failed to cut back on public spending in the years leading up to the recent crisis; a time when global factors, including low interest rates, exerted a large, positive impact on the Danish business cycle. Tigthening the stance of fiscal policy during economic booms is of paramount importance if fiscal policymakers wish to stimulate the economy in bad times.

The rest of this paper is structured as follows: In section 2, we introduce our SVAR model, and discuss the data, our choice of variables etc. We present our results as well as various extensions and robustness checks in section 3. In section 4, we use the estimated SVAR-model to undertake historical variance decompositions. Finally, section 5 concludes.

2 Empirical Model

Our baseline empirical model is a VAR model with 4 endogenous variables: Foreign trade-weighted GDP (F_t), domestic government spending (G_t), domestic private consumption (C_t), and domestic output (Y_t). For F_t, we use a weighted average of GDP in Germany and Sweden, Denmark's to most important trading partners, weighted by each country's share (in 1995) in the computation of the real effective rate of the Danish Krone by Danmarks Nationalbank (Pedersen and Plagborg-Møller, 2010). The structure of the VAR is the following:

$$X_t = \Psi + \Phi D_t + \Gamma Tr_t + \sum_{i=1}^{p} A_i X_{t-i} + \sum_{j=0}^{q} B_j Z_{t-j} + u_t, \qquad (1)$$

where $X_t = [F_t \;\; G_t \;\; C_t \;\; Y_t]'$ is the vector of endogenous variables. In alternative specifications, we replace government spending with a measure of tax receipts net of transfers, and we replace private consumption with private investment. Our baseline specification includes a constant, a linear trend Tr_t, and a crises dummy D_t which equals 1 during the recent financial crises and zero otherwise. $u_t = [f_t \;\; g_t \;\; c_t \;\; y_t]'$ is the vector of reduced-form residuals with variance-covariance matrix $Eu_t u_t' = V$. We include current and lagged values of GDP in the US as an exogenous variable, denoted Z_t. The exogenous variable is included as a proxy for the state of the global economy, including global technology shocks. By including this variable, we control for the fact that domestic output Y_t and foreign, trade-weighted output F_t are likely to be affected by common factors (such as a global recession). Without the inclusion of Z_t, the estimated effect on X_t of a shock to F_t would be upward biased. Moreover, we also assume that foreign trade-weighted GDP, F_t, is exogenous with respect to the domestic variable. The specification with a strictly exogenous block Z_t as well as a variable in X_t that is exogenous to the other variables in X_t but is affected by Z_t is due to Mojon and Peersman (2003), who employ a similar specification to model the effects of monetary policy in Austria, Belgium, and the Netherlands. They argue that these three countries do not affect, but are strongly affected by economic conditions in Germany, as well as 'global' economic factors, which are in turn assumed to be exogenous also with respect to the German economy.[4] The same description applies to the Danish economy, and we therefore find it natural to follow the specification suggested by Mojon and Peersman (2003). We verify that our exogeneity assumptions are in fact satisfied through block-exogeneity tests, which confirm our assumptions.[5]

The inclusion of a deterministic trend in the VAR allows us to use data in log-levels. However, following Blanchard and Perotti (2002), as a robustness check we also perform the analysis with the data in log-differences, allowing instead for a stochastic trend. We also need to choose which number of lags p of the endogenous variables to include. Table 1 in the appendix displays a number of tests and information criteria, to which we look for guidance on this choice. The three information criteria all point towards a low number of lags; 1 or 2. The vector Portmanteau test suggests using 2 (or 3) lags, while the vector test for normality of the residuals prefers a specification with 2 (or 4) lags. Finally, the likelihood ratio tests fail to reject that p lags are sufficient when p is between 2 and 6, except for $p = 4$. This test seems to favour 2 lags as well. Thus, while the data does not speak with a single voice on this issue, a choice of $p = 2$ lags seems a reasonable compromise for our baseline specification. We later change the number of lags as a robustness check.

2.1 The Data

Our dataset includes quarterly national accounts data spanning the sample from 1971:Q1 to 2011:Q2. We believe, however, that a regime shift occured in 1982 when Denmark shifted from a floating to a fixed exchange rate.[6] We therefore start our baseline estimation in 1983:Q1, although we include the years 1971-1982 as a robustness check later on. Moreover, we include a dummy for the recent crises, which equals 1 from 2008:Q4 onwards, and zero otherwise. While the recent crisis may not represent a regime shift, we consider it a time of unusual circumstances, which justifies the use of a dummy variable. For the domestic

[4] Mojon and Peersman (2003) include the short-term nominal interest rate in the US and a world commodity price index along with US GDP in the strictly exogenous block.

[5] More specifically, we perform an F-test of the null hypothesis that the three (lagged) domestic variables can be excluded from the regression equation for F_t against the alternative that the exclusion restrictions are not satisfied. We then test the null that the four (lagged) variables in X_t can be excluded from the regression equation for Z_t. The p-values for these tests are 0.404 and 0.565, respectively, implying that we fail to reject the null hypothesis of block exogeneity in both cases.

[6] Moreover, beginning in early 1983, an automatic indexation of wages and transfers to the rate of inflation was suspended. This is likely to have played an important role in bringing down the inflation rate.

variables, we use national accounts data from Danmarks Nationalbank's MONA database. We obtain GDP data for the US, Sweden and Germany from the OECD.

2.2 Identification Strategy

As already mentioned, our identification strategy follows the approach of Blanchard and Perotti (2002). They argue that it takes more than a quarter for fiscal policymakers to realize that a shock has hit the economy, decide on the appropriate response of fiscal policy, pass the relevant legislation, and implement the fiscal measures in practice. Thus, using quarterly data, there can be no discretionary response of government spending, so any simultaneous reaction of government spending to output or other variables must be due to automatic effects. These automatic effects can then be estimated outside the system. More specifically, we set up the following system of equations, which is essentially an open-economy version of that in Blanchard and Perotti (2002); except that we exclude taxes and instead include private consumption:

$$f_t = a_1 g_t + a_2 c_t + a_3 y_t + e_t^f, \tag{2}$$

$$g_t = b_1 f_t + b_2 c_t + b_3 y_t + e_t^g, \tag{3}$$

$$c_t = c_1 f_t + c_2 g_t + c_3 y_t + e_t^c, \tag{4}$$

$$y_t = d_1 f_t + d_2 g_t + d_3 c_t + e_t^y. \tag{5}$$

As mentioned above, $u_t = [f_t \ g_t \ c_t \ y_t]'$ contains the reduced-form residuals from the VAR regression, while $\varepsilon_t = \left[e_t^f \ e_t^g \ e_t^c \ e_t^y\right]'$ is the vector of orthogonalized, structural innovations to F_t, G_t, C_t, and Y_t, respectively. These two vectors are related in the following way:

$$u_t = C\varepsilon_t, \quad CC' = V, \tag{6}$$

where V is the variance-covariance matrix of the residuals, as noted above. We need to impose identifying restrictions that allows us to pin down uniquely the matrix C, as this allows us to back out the structural innovations and compute meaningful impulse-responses.

In the system of equations above, (5) states that unexpected movements in domestic GDP (y_t) within a quarter can arise due to unexpected movements in foreign GDP (f_t), unexpected movements in private (c_t) or public consumption (g_t), or structural shocks to output (e_t^y). The interpretation of the other equations is similar. Given our assumption that foreign GDP is exogenous with respect to the domestic variables, we impose that $a_1 = a_2 = a_3 = 0$. Moreover, we assume that if there is any automatic effect on public spending of changes in foreign output, this effect occurs via the effect of foreign output on domestic output, so that $b_1 = 0$. Similarly, we assume that changes in private consumption does not cause automatic changes in government spending *on top of* a potential effect through output, i.e. that $b_2 = 0$.

The parameter b_3 measures the automatic effects that changes in output might have on public spending within a quarter. As discussed by Caldara (2011), as well as in section 3.3 of the present paper, setting a value for this parameter is not innocuous, as this has substantial effects on the estimated impact multiplier of an increase in public spending. In the literature, this parameter is typically set to zero; see e.g. Blanchard and Perotti (2002), Monacelli and Perotti (2008, 2010), or Ravn, Schmitt-Grohé and Uribe (2012). An exception is Bergman and Hutchison (2010), who set the parameter to -0.2 for Denmark, based on a study by Giorno *et al.* (1995). That elasticity is found by computing the elasticity of unemployment-related expenditures to output, and multiplying by the share of unemployment-related expenditures to total government expenditure. However, unemployment-related expenditures are excluded from the measure of public consumption used in the present study, suggesting an elasticity of zero. Conversely, Caldara (2011) argues that b_3 is likely to be positive, citing evidence by, among others, Lane (2003) that government consumption tends to be pro-cyclical in most OECD countries, including Denmark. This result is obtained at the annual level, however, and does not necessarily carry over to quarterly data. In our baseline scenario, we therefore follow the literature and set $b_3 = 0$, while we use different values for this parameter as robustness checks; bearing in mind that it is probably more likely to be positive than negative for our data due to the results of Lane (2003).

To pin down the parameters in the final two equations, we need to take a stand on whether private consumption or output is determined first. We assume that private consumption affects output within a quarter, but not the other way around; i.e. $c_3 = 0$ but $d_3 \neq 0$. This choice turns out be unimportant for our results. We then construct the cyclically adjusted government spending residuals; $g'_t = g_t - b_3 y_t$ ($= g_t$ when we set $b_3 = 0$). These residuals are uncorrelated with the structural innovations to output and consumption, e^y_t and e^c_t, allowing us to use them as instruments for g_t in regressions of c_t and y_t on the right-hand side variables in (4) and (5). Likewise, we need the structural innovations to foreign output, e^f_t, to be uncorrelated with e^y_t and e^c_t. This is ensured by the inclusion of US GDP as an exogenous variable in the original VAR, as this variable controls for global shocks such as productivity shocks that are likely to affect both the foreign and the domestic economy. Hence, we first estimate c_1 and c_2 by regressing c_t on e^f_t and g_t, with g'_t as instrument for g_t.[7] We then estimate d_1, d_2, and d_3 by regressing y_t on e^f_t, c_t and g_t, again using g'_t as an instrument.[8]

Having pinned down all parameters, it is straightforward to solve the system above for the structural shocks as functions of the reduced-form residuals obtained from the VAR and

[7] Recall that $e^f_t = f_t$.

[8] Of course, when we set $b_3 = 0$ so that $g'_t = g_t$, the use of g'_t as an instrument in practice becomes redundant. On the other hand, when we set $b_3 \neq 0$, or in the specification with taxes instead of government spending, this step becomes relevant.

the estimated coefficients. Moreover, we can compute the coefficients in the matrix C from these parameters, allowing us to obtain the impact effects on the endogenous variables of an orthogonalized, structural innovation to one of these variables, which is needed for impulse responses. The impact effects of a shock to government spending are given by:

$$f_t = 0, \tag{7}$$

$$g_t = \left[1 + b_3 \frac{d_2 + c_2 d_3}{1 - b_3 d_2 - b_3 c_2 d_3}\right] e_t^g, \tag{8}$$

$$c_t = \left[c_2 + \frac{(b_3 c_2)(d_2 + c_2 d_3)}{1 - b_3 d_2 - b_3 c_2 d_3}\right] e_t^g, \tag{9}$$

$$y_t = \frac{d_2 + c_2 d_3}{1 - b_3 d_2 - b_3 c_2 d_3} e_t^g. \tag{10}$$

It should be noted that in our specification with government spending, when we set the elasticity of government spending to output $b_3 = 0$, the identification strategy collapses to a standard Choleski decomposition with government spending ordered before consumption and output. However, we use the structural identification scheme outlined above for at least two reasons: First, it allows us to replace government spending with taxes, for which the output elasticity is surely not zero. Second, we are able to relax the assumption of a zero output elasticity of government spending as a robustness check. As described in subsection 3.3, it turns out that our results are very sensitive to this parameter.

3 The Effects of Fiscal Policy

In this section, we present and discuss our results, including a number of robustness checks. We begin by computing impulse responses to an increase in government spending.

3.1 Impulse Responses and Fiscal Multipliers

We first look at orthogonalized impulse responses to a shock to government spending. Given the exogeneity of the foreign variables, these are not affected by this shock, so we report impulse responses only for the domestic variables. Consider first our baseline scenario with variables in log-levels, as depicted in Figure 1.

As the figure makes clear, the increase in government spending is quite persistent, remaining significantly above zero for some 3 years after the shock. Nevertheless, the effect on output dies out much faster. After a large initial increase, output quickly reverts back to its original level. The reaction of output is significant only during the first year (except

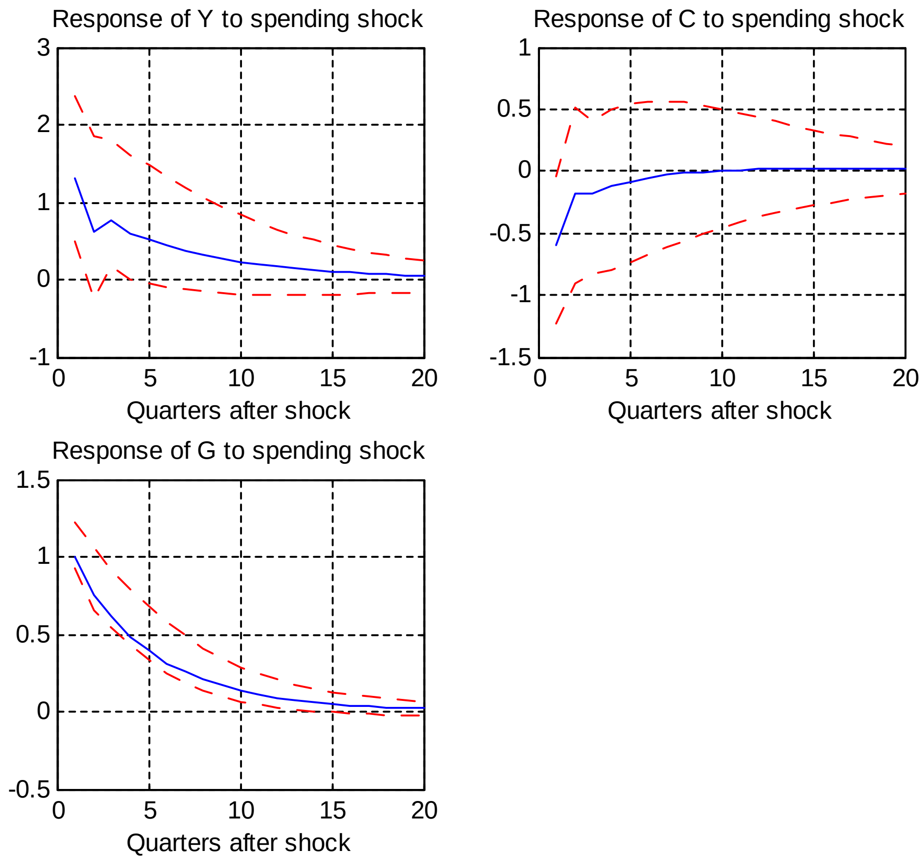

Figure 1: The dynamic response of each variable to a unit shock to government spending. Dotted lines indicate bootstrapped 95 % error bands. The error bands are computed using Hall's (1992) bootstrap method with 10,000 replications.

for the second quarter after the shock). Somewhat surprisingly, we observe a borderline significant drop in consumption on impact. From the second quarter onwards, the reaction of consumption is small and insignificant.

We have converted the impulse responses in Figure 1 so that the fiscal multiplier is directly observable. The impact multiplier of government spending on output is 1.31, implying that a 1 DKR rise in government spending causes an immediate increase in GDP of 1.31 DKR. This multiplier is rather high, although well within the interval 0.8-1.5 highlighted by Ramey (2011b). However, we observe that the multiplier quickly decreases. A year after the shock, the multiplier is 0.6, after which it becomes insignificant. The government spending multiplier is above 1 only on impact, i.e. in the same quarter in which government spending is increased. These findings are in line with the theoretical arguments in the introduction.

In the very short run, fiscal stimulus is quite effective in Denmark, as prices are sticky, and neither the nominal interest rate nor the nominal exchange rate can adjust. However, as soon as prices start to adjust, the effects of fiscal stimulus quickly die out, as the Danish economy loses its competitiveness against its trading partners. The cumulative multiplier, computed as the accumulated increase in output divided by the accumulated increase in government spending, is found to be 1.34.[9] This number is comparable to the estimate of Ilzetzki *et al.* (2010), who study fiscal policy in 44 countries, and find a cumulative multiplier of 1.5 in countries operating under a fixed exchange rate regime. These authors estimate a much smaller impact effect, however. Our finding that the impact multiplier and the cumulative multiplier are almost identical reflects that the effect on output declines at around the same rate as the response of spending itself, as illustrated in the figure.

Most studies based on the approach of Blanchard and Perotti (2002) tend to report an increase in consumption after a shock to government spending (e.g. Gali *et al.*, 2007). Our finding of a drop in consumption is instead more in line with studies using the approach of Ramey and Shapiro (1998). In particular, it may seem puzzling that the government spending multiplier is above 1 despite the drop in consumption. In results not reported, we find that this is explained by an increase in private investment on impact.[10]

3.2 Subsample Stability

While much of the debate about the effects of fiscal policy has centered around the size of *the* government spending multiplier, it is important to note that this multiplier is far from constant. Instead, it is likely to vary substantially over time and across different economic situations. For the US, for example, Perotti (2005) and Billbie *et al.* (2008) have demonstrated that the fiscal multiplier has been declining over time. Billbie *et al.* (2008) argue that this can be explained by two factors: Increased asset-market participation by households, and a more active monetary policy since the beginning of the 1980's. Increased asset-market participation allows households to smooth consumption over time, lowering their sensitivity to shocks affecting current income, such as fiscal policy shocks. This mitigates the effect described by Gali *et al.* (2007). A more active stance of monetary policy implies a stronger interest rate reaction to the inflationary effects of an expansionary fiscal policy, inducing an increase in the real interest rate which dampens the effect on economic activity.

To evaluate how the fiscal multiplier in Denmark has evolved over time, we extend our analysis back to 1971, and then split the entire sample into four different subsamples; one for each decade in our dataset. Table 1 shows the impact multiplier for various subsamples, i.e. the increase in output (in DKR) in the same quarter as government spending is increased by

[9] We compute the cumulative multiplier at a horizon of 20 quarters, after which the response of both output and spending itself is practically zero.

[10] The increase in investments is large on impact, after which it quickly reverts back around zero. In effect, the impulse response of investments mirrors that of private consumption.

1 DKR. As the table illustrates, the government spending multiplier varies substantially over time. First, when the years 1971-1982 are included in the baseline regression, the impact multiplier drops to 1.17. This indicates that the multiplier was lower in the 1970's, but also that our baseline result is not too sensitive to our choice of sample period. Second, we observe that fiscal stimulus seems to have become more effective in the latter two decades of our sample than in the 1970's and 1980's. In particular, the multiplier is below one in the first two decades, but above one after 1990. The confidence intervals are very wide, however, in large part because of the short subsamples with only 40 quarterly observations each. In fact, strictly speaking, the only conclusion we can safely draw from these numbers is that the multiplier was lower in the 1980's than in the 2000's as well as in the longer samples. Nevertheless, we have some confidence in the finding that discretionary fiscal policy has been more effective in the last two decades, despite the interesting fact that our findings are in opposition to results obtained in studies using US data, as mentioned above. In the 1970's and well into the 1980's, Denmark's public finances were very unsound, and inflation and nominal interest rates were often in double digits. In such an economic environment, fiscal stimulus is likely to have led to expectations of higher inflation and interest rates, and in turn to expectations of a devaluation of the Danish Krone, which was not uncommon in the 1970's. While a fixed exchange rate was adopted in 1982, credibility around a currency peg is not gained overnight. On the other hand, during the 1990's and 2000's the Danish economy has generally been characterized by a credibly fixed exchange rate and sound public finances, facilitating a more effective conduct of discretionary fiscal policy. As discussed above, larger effects of fiscal policy under fixed than under flexible exchange rates are in line with a range of theoretical models as well as empirical evidence. Furthermore, a number of reforms have increased the flexibility of the Danish labor market considerably over our sample, which is likely to have contributed to the enhanced effectiveness of fiscal policy. On the other hand, the increasing openness to trade of the Danish economy over our sample is likely to have lowered the fiscal multiplier over time, as a larger share of government spending is 'leaked' from the home economy (Beetsma and Giuliodori, 2011). In sum, while our results contrast with those of Perotti (2005) and Billbie *et al.* (2008) for the US, there is a number of reasons for this discrepancy. Furthermore, there is no reason to believe that the fiscal multiplier will be even larger in the future, as Denmark's fixed exchange rate is now surrounded by a very high credibility, and its public finances are relatively solid. The channels for obtaining larger effects of fiscal policy thus seem to have been exhausted.

Table 1: Impact multipliers for different subsamples.

Subsample	Multiplier	95 % Confidence Interval
1983-2011	**1.31**	[0.50;2.36]
1971-2011	**1.17**	[0.54;1.90]
1971-1980	**0.78**	[-0.05;1.97]
1981-1990	**0.33**	[-1.31;1.97]
1991-2000	**1.03**	[-0.22;3.10]
2001-2010	**1.54**	[0.45;3.45]

Note: The crisis dummy is included in the regressions for 1983-2011 and 1971-2011, but not in the regression for 2001-2010. The confidence intervals are computed using the bootstrap method of Hall (1992) with 1000 replications. Note that because confidence intervals are bootstrapped, they are not necessarily symmetric. All specifications include a deterministic trend.

3.3 Robustness

While the previous subsection offered a first glance at the robustness of the estimated fiscal multiplier, we now investigate this issue in more detail. We display impulse responses only when these are somewhat different from those in Figure 1, although all results are available upon request.

First, we allow for quarterly dummies, as suggested by Blanchard and Perotti (2002). This does not change our results in any relevant aspect. Next, we observe that our results are also practically identical if we exclude the crisis dummy from our baseline specification. The impulse responses look very much like those in Figure 1.

A more interesting robustness check is to investigate the sensitivity of our results to the number of lags in the VAR, which we set to 2 in our baseline estimation (we always choose the same number of lags for the exogenous variable as for the endogenous variables). With 1 lag, the impact multiplier is practically identical to the baseline, while with 3 lags, it rises slightly to 1.44. The impulse responses do not change much. With 4 lags, however, the results change considerably, as witnessed by Figure A.1 in the appendix. In particular, the initial drop in consumption is now small and insignificant. Instead, the response of consumption becomes positive for a number of periods; significantly so from 3 to 6 quarters after the shock. As a result, the response of output no longer reaches its peak on impact, but instead in the third quarter after the shock. The response of output is significantly positive until two years after the shock. The findings of a positive response of consumption and a delayed peak effect on output are in fact consistent with the results from a number of studies for other countries, including Blanchard and Perotti (2002) for the US. Indeed, Blanchard and Perotti use 4 lags in their study, although they do not report tests or information criteria to support this choice. Thus, while our data strongly favours the use of a model with a low number of lags, as already discussed, the fact that our results come closer to mimicking those of Blanchard and Perotti when we imitate their choice of lags is an interesting finding.

The results above were obtained with data in log-levels. To address concerns about potentially non-stationary variables, we perform a similar analysis allowing for a stochastic trend in the data instead of a deterministic trend. With data in log-differences, the VAR regression and the structural identification strategy are the same, with the exception that the linear trend Tr_t is removed from the VAR. We display the impulse responses from this analysis in Figure A.2a in the appendix. As these impulse responses fluctuate a lot, we display in figure A.2b the same impulse responses after smoothing them using a Hodrick-Prescott filter. As these figures illustrate, it is hard to draw any firm conclusions from this specification, as the impulse responses of output and consumption are insignificant most of the time. The impact effect on output is significantly positive, though, with an impact multiplier of 1.09, i.e. somewhat lower than in the model with a deterministic trend. As for consumption, we still observe a drop on impact, but now the response turns positive in the next few quarters. The consumption response is never significantly different from zero under this specification.

Finally, we want to evaluate the consequences of different assumptions in our identification scheme. In particular, we consider the robustness of the estimated impact multiplier of government spending with respect to different values of the elasticity of government spending to output within the quarter (b_3), which was set to zero in our baseline specification. As demonstrated by Caldara (2011), this parameter has a heavy influence on results based on US data. This turns out also to be the case for our study of Denmark. Figure A.3 in the appendix shows how our estimate for the impact multiplier changes when we vary the value of b_3. As the figure illustrates, the impact multiplier is highly sensible to the value of this parameter. For example, if b_3 is allowed to take on a modest value of 0.1, the impact multiplier drops to 0.56, compared to our baseline estimate of 1.31. Similarly, if we set $b_3 = -0.1$, the multiplier is as high as 1.92.[11] The intuitive explanation for this finding is the following: If for example the automatic elasticity of government spending to output is negative ($b_3 < 0$), the increase in output brought about by a positive shock to government spending will in itself induce a fall in government spending, all else equal. As a result, the eventual increase in government spending will be small, while the increase in output is the same (abstracting from a small second-round effect). Hence, the estimated multiplier will be larger.

We are therefore able to confirm the results of Caldara (2011); in fact, the sensitivity of the multiplier seems even bigger in our case. The large sensitivity of the results is an obvious shortcoming of the identification strategy of Blanchard and Perotti (2002) that has until recently largely been ignored in the literature. As discussed in subsection 2.2, the parameter b_3 is likely to be close to zero, but as we have demonstrated, even small deviations from zero

[11] In results not reported, we observe that consumption rises on impact when b_3 is sufficiently low. In fact, we find that this explains the divergence between the negative consumption response in the present study and the positive response obtained by Bergman and Hutchison (2010), who set $b_3 = -0.2$.

lead to substantial effects on our results. We have argued that the parameter is most likely to be slightly positive, implying that our estimated multiplier of 1.31 should be adjusted downwards. More than anything, however, the above analysis indicates that our estimated multiplier should be interpreted with care.

3.4 Effects of Taxes

As discussed by Blanchard and Perotti (2002), the structural VAR model presented above favours a view of fiscal policy as working primarily through the demand side of the economy. While this seems a reasonable assumption for government spending, we believe it provides only a partial account of how changes in taxes affect the economy. Changes in income taxes, for example, are likely to affect the economy's supply side through changes in labor supply as well as the demand side via a change in disposable income. Therefore, in contrast to Blanchard and Perotti (2002), we choose not to include taxes along with government spending in our baseline specification. Nevertheless, in this subsection we attempt to gain at least some insight on the effects of taxes by including them in our SVAR, although these results should therefore not be interpreted as a complete account of the effects of tax changes.

We use a measure of tax revenues net of transfers. We add direct taxes (including corporate taxes and capital gains taxes), indirect taxes, and social contributions, and subtract transfers to households. We then insert taxes (T_t) instead of government spending (G_t) in our baseline VAR as presented in (1) with two lags, a constant, a deterministic trend, and with the crises dummy included in the block of exogenous variables.

The structural system is essentially the same as the one presented in subsection 2.2, with taxes replacing government spending. We also stick with the same identifying assumptions. The only difference is related to the elasticity of the tax revenue with respect to changes in output, which we denote b_3^T. In contrast to the specification with government spending, this elasticity is now unlikely to be zero, as a rise in GDP will lead to an increase in the tax base and in turn, the tax revenue. In order to pin down b_3^T, we decompose the total tax revenue into different types of taxes (income taxes, corporate taxes, etc.). We then compute the elasticity of each type of tax with respect to changes in output, and weigh these together to obtain a measure of the elasticity of total tax revenues. The method is described in detail in appendix B. We arrive at a value of $b_3^T = 2.09$.

We compute impulse responses to an increase in the tax revenue. These are shown in figure A.4 in the appendix. As illustrated, an increase in taxes leads to a drop in output and consumption, although the latter is not significant. The estimated tax multiplier is 0.78 on impact, which is smaller than the government spending multiplier. Given the focus of the SVAR approach on the demand side effects of taxes, as described above, this finding is unsurprising. However, a number of recent studies that pay more attention also to supply-side effects have challenged this result, and tend to find that the tax multiplier is at least as large as the spending multiplier (see Alesina and Ardagna, 2010; Romer and Romer, 2010; or Mertens and Ravn, 2012).

We further observe that output quickly returns to its initial level, as the response is numerically quite small from the second quarter after the shock onwards. Due to the drop in output and the resulting drop in the tax base, tax revenues quickly return to zero.[12] Finally, we explore the sensitivity of the tax multiplier to the value of the parameter b_3^T. It turns out that the tax multiplier is much more robust than the government spending multiplier, in line with the findings of Caldara (2011). In particular, if we increase b_3^T to 2.5, the estimated impact multiplier increases only to 0.79. If instead we set $b_3^T = 1.5$, the multiplier drops to 0.65.

4 What Drives the Danish Business Cycle?

In this section, we use our estimated, structural VAR model to decompose recent business cycle fluctuations in Denmark. We first undertake a historical decomposition to shed light on the contribution of various shocks to fluctuations in output at specific points in time. Later on, we perform a variance decomposition of the endogenous variation in our VAR-model.

4.1 Historical Decompositions

This subsection follows the approach of Lindé (2003). We first obtain the trend growth in the exogenous variable Z_t (GDP in the US) by estimating and then simulating a VAR with Z_t as the dependent variable and two lags of Z_t as regressors, along with a constant and a deterministic trend. In the simulation, we do not add the residuals, so that we obtain a simulated variable $\overline{Z}_t$ describing the trend in US GDP. The next step is to simulate the trend of the four endogenous variables in X_t, which we will denote by $\overline{X}_t = \left(\overline{F}_t\ ,\ \overline{G}_t\ ,\ \overline{C}_t\ ,\ \overline{Y}_t\right)'$. This is done by simulation of the following regression:

$$\overline{X}_t = \Psi + \Phi D_t + \Gamma Tr_t + \sum_{i=1}^{p} A_i \overline{X}_{t-i} + \sum_{j=0}^{q} B_j \overline{Z}_{t-j}. \tag{11}$$

We use the first two quarters in our sample to start up the simulation. We then feed our estimated VAR with lagged values of the trend in the endogenous as well as the exogenous variables. Once again, note that we do not add any residuals to the simulation. Once the trend is obtained, we can easily compute the deviations from trend in each variable by subtracting the trend from the actual, observed variables.

[12] Note that the shock to tax revenues has been normalized to 1, so as to facilitate comparison with the shock to government spending. The response of tax revenues, however, is smaller than 1 already on impact, as the rise in taxes implies a drop in output, and hence in the tax base.

We can decompose these deviations from trend into contributions from each of our 4 endogenous variables, as well as from Z_t. As described in subsection 2.1, we have the following link between the reduced-form residuals from the VAR (u_t) and the structural innovations (ε_t):

$$u_t = C\varepsilon_t,$$

where the matrix C can be recovered, as already described. Having backed out the structural shocks, we can isolate, for example, the contribution of structural innovations to government spending to deviations of output from its trend. This is done by 'turning off' all other structural shocks than those to e_t^g; i.e., simply setting them to zero. We then perform a new simulation of (11), in which we feed the VAR with the structural shocks to government spending in each step. The same can be done for each of the four endogenous variables. As for Z_t, we simply simulate (11) using the actual values of Z_t instead of the simulated trend $\overline{Z}_t$.

Figure 2 shows the deviations of output from its simulated trend over the course of our sample, as well as the share explained by structural shocks to government spending. The share of other shocks is illustrated in figure A.5-A.7 in the appendix. As the figure illustrates, shocks to government spending do not account for a very large share of output fluctuations. The reason is that by construction, the simulations above assign large explanatory power to variables that display large deviations from their trend in any given period. As government spending follows its trend growth quite closely during most of our sample, its deviations from trend are simply too small to account for a very large share of output fluctuations. Moreover, it is noteworthy that there is little evidence of systematic, countercyclical fiscal policy; at least as measured by the level of government spending. In particular, the stance of fiscal policy appears to have been 'too tight' during the recession in the late 1980's and early 1990's. Likewise, during the economic booms in the second half of the 1990's and the years 2004-2007, the growth rate of government spending was not reduced relative to its historical trend, despite the fact that, as evidenced by figure A.5 in the appendix, global factors exerted a strong, positive effect on the Danish business cycle.[13]

[13] Moreover, a recent study by Ravn (2012) suggests that, as a consequence of Denmark's fixed exchange rate towards the euro, the Danish interest rate was substantially lower than what would have been prescribed by a Taylor rule for Denmark in the years 2005-2007. This would in turn have called for an even tighter stance of fiscal policy during these years.

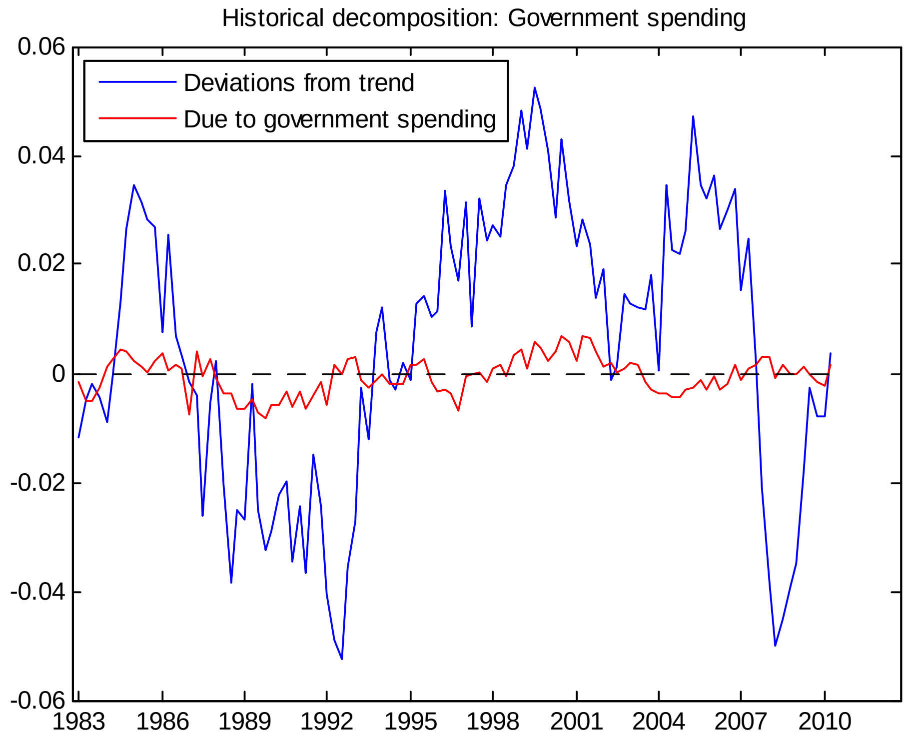

Figure 2: Historical decomposition. The blue line shows deviations in output growth relative to its trend growth. The red line shows the share explained by deviations in the growth rate of government spending relative to its trend.

Furthermore, figure A.5 in the appendix shows that the Danish business cycle has been mainly driven by global factors during the period in question. Given the size and openness of the Danish economy, this is an unsurprising finding. The figure suggests that episodes such as the US recession in 1990-91, the tech-boom in the 1990's, and the financial and economic crisis beginning in 2008 have large and direct spill-over effects on the Danish economy. Figure A.6 shows that the contribution from Denmark's two most important trading partners, Germany and Sweden, is much less important. The post-reunification boom in Germany in 1990-91 can be clearly identified, but its effect on the Danish economy seems to be dominated by the concurrent recession in the US. Finally, figure A.7 shows the contribution that can be attributed to other domestic shocks, i.e. fundamental shocks to Y_t or C_t. Throughout the 1980's, these shocks account for a remarkably large share of the movements in GDP, suggesting that the economic boom in Denmark in the mid-1980's and the subsequent recession to a large extent were 'homegrown'. In 1982, the new, conservative government announced a number of economic reforms, including, as already mentioned, a currency peg towards the German D-Mark as well as the suspension of an automatic indexation of wages and transfers. This confidence boost set off an economic expansion. In 1986, as the Danish economy showed signs of overheating, a new set of reforms were enacted, including regulations on real estate mortgage lending and a tax reform, which effectively limited credit-financed consumer spending, and put a sudden end to the boom. For the remainder of the sample, domestic shocks have been less important to the business cycle; although a substantial, positive contribution appears in 1993-94 following the appointment of a new, social democratic government and a new set of reforms, including a reform of the labor market.

4.2 Variance decompositions

We can shed further light on the driving forces behind the Danish business cycle by examining the importance of each shock at various points of the frequency domain. Unfortunately, this method can be applied only to the 4 endogenous variables in X_t, as the method makes use of the variance-covariance matrix V of the structural VAR-regression in (1), in which no shock related to the exogenous variable (Z_t) appears, as it does not have a structural shock. As a result, the variance decompositions below ignore the contributions from global factors. Nevertheless, it still offers interesting insights on the relative importance of the shocks to the remaining four variables.

We follow the approach to variance decompositions taken by Altig *et al.* (2005). The details of the method are outlined in appendix C. This method allows us to decompose the variance of each of the four endogenous variables for any frequency ω in the frequency domain. In this way, we can investigate the relative importance of the four shocks at various frequency intervals, uncovering the importance of these shocks for short-run and long-run movements in the four variables. As an example, one could suspect that fiscal policy shocks are more important in explaining output over the span of the business cycle than in explaining the long-run trend. The present approach will allow us to answer such questions.

Table 2: Variance decomposition for output

	f_t-shocks	g_t-shocks	c_t-shocks	y_t-shocks
Low frequencies	0.2702	0.0934	0.3787	0.2577
Business cycle freq.	0.1887	0.0871	0.1763	0.5480
High frequencies	0.0187	0.0864	0.0831	0.8118
All frequencies	0.2054	0.0901	0.2652	0.4393

Table 2 shows the variance decomposition for output. Each row shows how much of the variation in output at, say, low frequencies, can be attributed to structural shocks to each of the four variables. In other words, the numbers in each row sum up to 1. We follow Altig *et al.* (2005) and define high frequencies as up to 5 quarters, business cycle frequencies as 6 to 32 quarters, and low frequencies as more than 32 quarters. The table reveals that shocks to government spending explain less than 10 % of the variation in output at all frequencies. The importance of government spending shocks is almost constant across the frequency domain. This confirms the findings from the historical decomposition above. We conclude that government spending has not played a very important role in driving the Danish business cycle. Furthermore, the table shows that shocks to output in Germany and Sweden are a substantial contributor to output fluctuations at low and medium frequencies, but not at high frequencies. Finally, fundamental shocks to output or private consumption are the two main drivers of output variations, especially in the short run, suggesting that domestic factors account for a somewhat surprisingly large share of output fluctuations. A similar conclusion is reached by Dam and Linaa (2005).[14] Recall, however, that the numbers in table 2 concern only the part of output variations that remain after controlling for global economic factors by regressing the endogenous variables on US GDP, which was shown in the previous subsection to have very large effects on the Danish economy.

5 Conclusion

We have presented an array of empirical findings about the effects of fiscal policy in Denmark that can broadly be summarized as follows: First, an increase in government spending has a rather large impact on output in the very short run, with a fiscal multiplier around 1.3. However, the expansionary effects are very short-lived, as the multiplier is above 1 only on impact, and the response of output becomes insignificant after about a year. As argued in the introduction, these results suggest that the interest rate effect under a fixed exchange rate outweighs the leakage effect following from a large degree of openness, as traditionally believed in the literature. Our results are therefore in line with economic theory. Second, as for the effect on consumption, our results are somewhat inconclusive, but tend to suggest that private consumption goes down after an increase in government spending. Third, the fiscal multiplier is not constant. In particular, fiscal stimulus seems to have become more effective in the last two decades compared to the 1970's and 1980's. Fourth, an increase in taxes depresses economic activity, although the tax multiplier is smaller than the spending multiplier. Finally, the estimated government spending multiplier is highly sensitive to the automatic elasticity of government spending to output.

A number of authors have used empirical results about fiscal policy to evaluate competing macroeconomic theories and models (Blanchard and Perotti; 2002, Gali *et al.*; 2007). As discussed by Blanchard and Perotti, for example, an increase in private consumption in

[14]Dam and Linaa (2005) estimate a DSGE model for Denmark, and report that the main driver of output variations, especially in the long run, is stochastic movements in the labor supply. Our SVAR-model is much more rudimentary, and in particular does not feature shocks to the labor supply. In our setup, however, such shocks are likely to show up as fundamental shocks to y_t; or perhaps to c_t (through the consumption/labor decision of households).

response to a government spending shock is consistent with traditional, Keynesian models, in which a household's consumption is a function of its current income. This will tend to increase, depending on how the fiscal stimulus is financed. In contrast, a drop in consumption suggests that households behave in a Ricardian fashion, as assumed in standard neoclassical models such as the Real Business Cycle model, as well as in New-Keynesian models. In these models, consumption is instead determined by lifetime income, which goes down due to the increase in the present value of future tax payments. The results in the present paper seem to lend more support to the latter class of models, in which households display at least some degree of Ricardian behaviour, although the data does not allow us to draw any firm conclusions in this respect.

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Appendix A: Additional Tables and Figures

Table A1: Specification tests for the VAR

# of lags	Akaike	Schwartz	Hannan-Quinn	Portmanteau	Normality	Likelihood Ratio
1	**-47.80**	**-46.79**	**-47.39**	339.29 (0.0049)	24.18 (0.0071)	N/A*
2	**-47.80**	-46.16	-47.17	**299.62** (0.0172)	**18.43** (0.0482)	**29.01** (0.2635)
3	-47.66	-45.39	-46.74	275.41 (0.0122)	25.61 (0.0043)	32.75 (0.1374)
4	-47.58	-44.69	-46.41	267.28 (0.0010)	20.61 (0.0240)	50.53 (0.0018)
5	-47.56	-44.24	-46.33	231.63 (0.0027)	24.78 (0.0058)	29.34 (0.2500)
6	-47.69	-43.54	-46.00	211.79 (0.0007)	32.39 (0.0003)	29.84 (0.2303)

Note: The first 3 columns simply report the information criteria. The last 3 columns report test statistics, with p-values in brackets. In calculating these tests, we have included also the exogenous variable (US GDP) in the block of endogenous variables, as suggested by Lindé (2003). For the LR test of 1 lags versus 2, we encounter the problem that the determinant of the variance-covariance matrix of the VAR with 1 lag is too close to zero, so that the test statistic takes on a value of -1126.7, which is not very meaningful. We therefore discard this test.

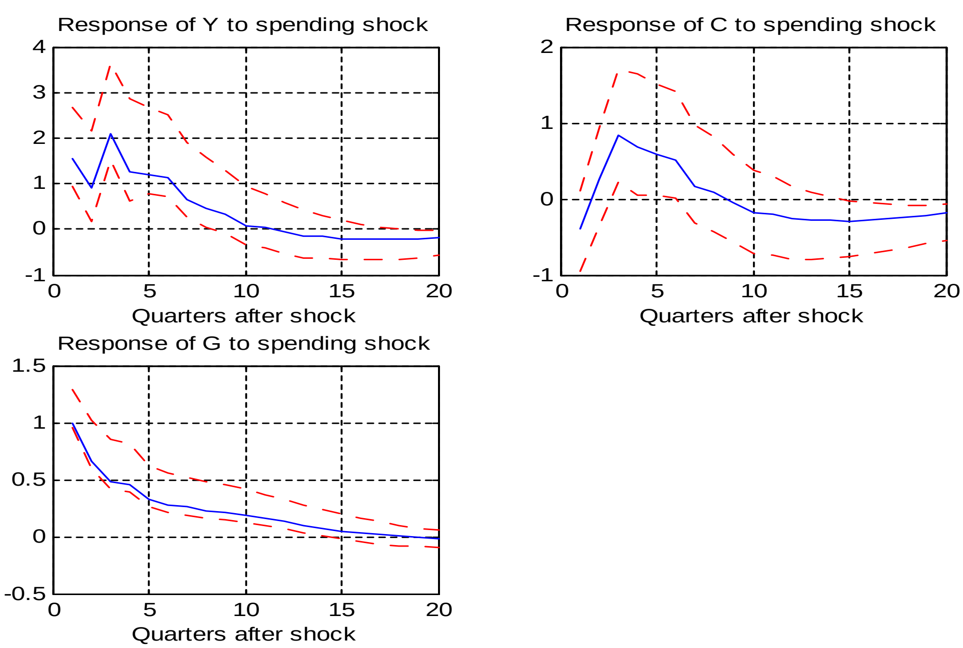

Figure A.1: The effects of a shock to government spending, specification with 4 lags instead of 2, deterministic trend.

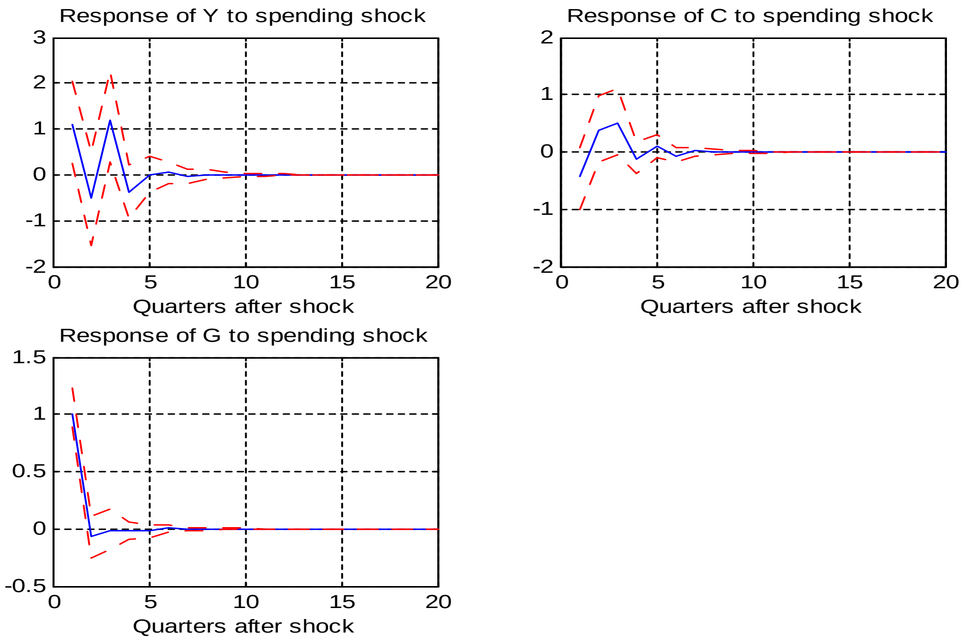

Figure A.2a: The effects of a shock to government spending, specification with stochastic trend.

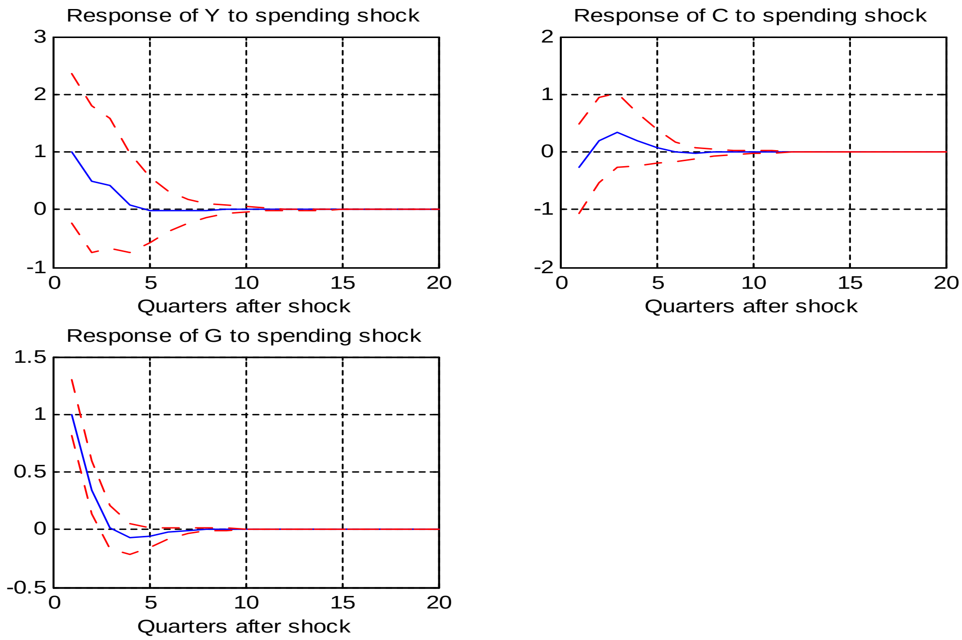

Figure A.2b: The effects of a shock to government spending, specification with stochastic trend, impulses HP-filtered with $\lambda = 1$.

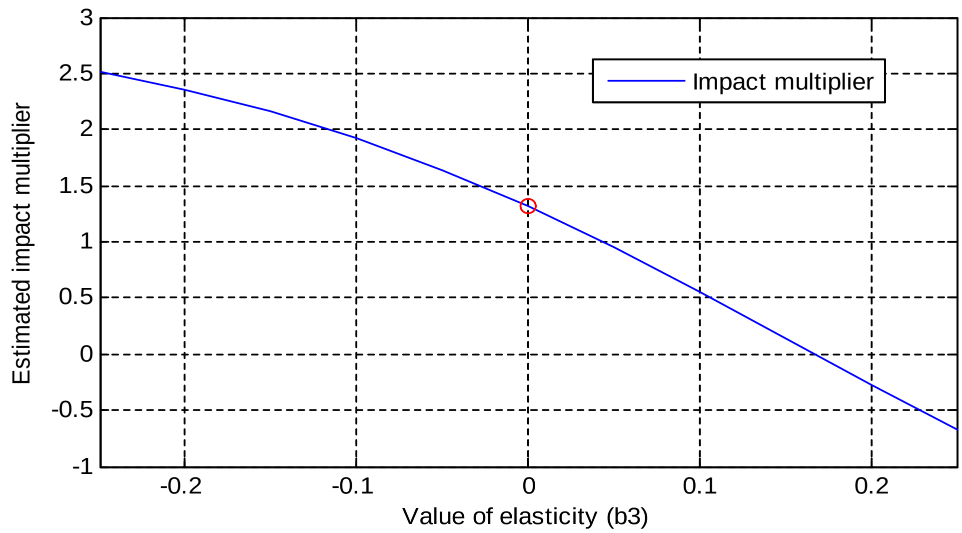

Figure A.3: The sensitivity of the estimated impact multiplier of government spending to the elasticity of government spending to output. The red dot indicates our baseline estimate of $b_3 = 0$.

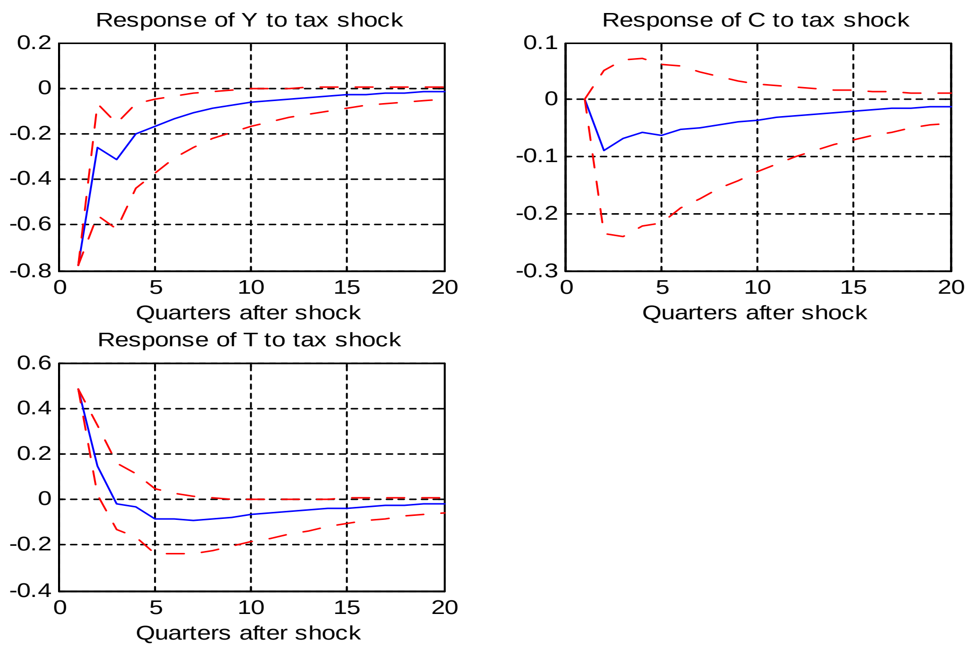

Figure A.4: The effects of an increase in net tax revenues.

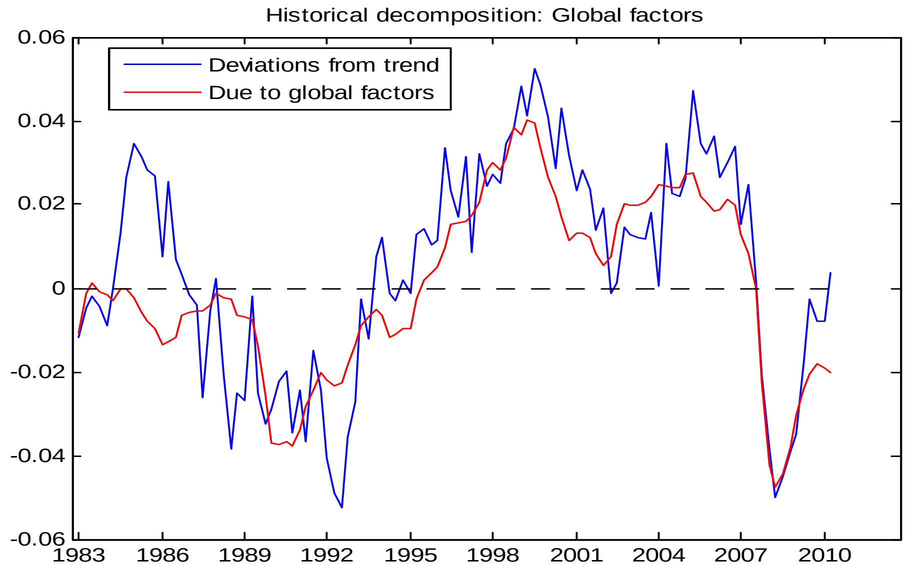

Figure A.5: Historical decomposition. The blue line shows deviations in output growth relative to its trend growth. The red line shows the share explained by deviations in the growth rate of US GDP relative to its trend.

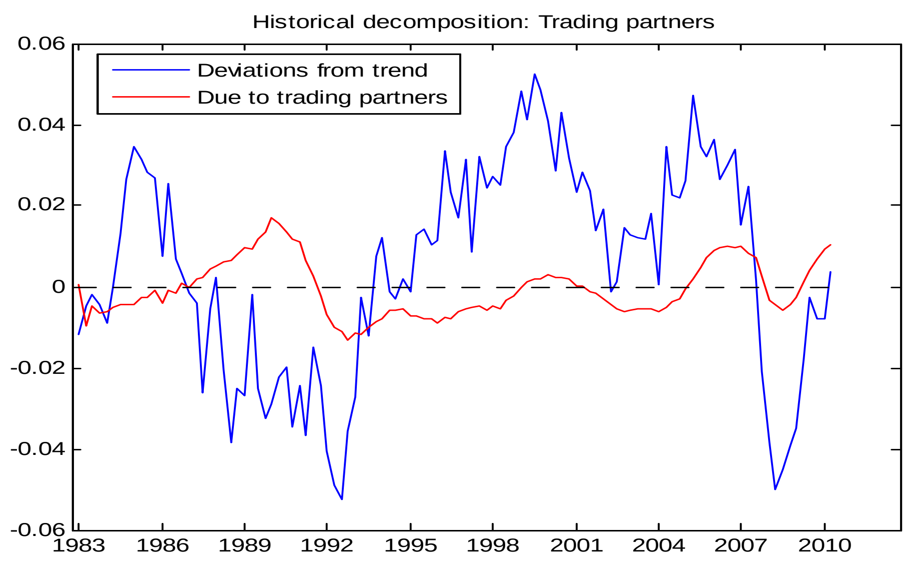

Figure A.6: Historical decomposition. The blue line shows deviations in output growth relative to its trend growth. The red line shows the share explained by deviations in the growth rate of F_t relative to its trend.

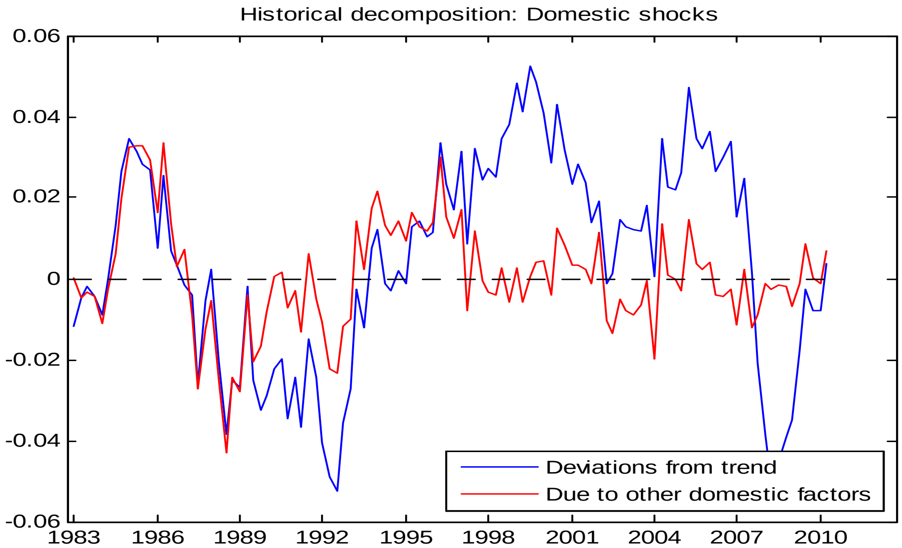

Figure A.7: Historical decomposition. The blue line shows deviations in output growth relative to its trend growth. The red line shows the share explained by deviations from trend in other domestic variables than government spending.

Appendix B: Computing the Output Elasticity of Taxes

This appendix provides a detailed account of how we obtain an estimate of the elasticity of taxes to changes in output, as employed in subsection 3.4.

We decompose the total tax revenue into four categories: Income taxes, corporate taxes, indirect taxes, and social contributions. We then obtain the elasticity of each of these types of taxes from a study by the OECD (Girouard and André, 2005). Moreover, recall that we use a measure of taxes net of transfers. We therefore also need an estimate of the elasticity of transfers to changes in output. Finally, we weigh the elasticities together according to their average share of total net revenues during our sample period.

The tax elasticities estimated by Girouard and André (2005) for Denmark are the following: Income taxes; 1.0. Indirect taxes; 1.0. Corporate taxes; 1.6. Social contributions; 0.7. We refer the reader to that study for further details.

As for transfers, we follow Girouard and André and assume that unemployment benefits is the only type of transfers that contains a significant cyclical component. We therefore compute the sample average share of unemployment-related transfers to total transfers, and multiply this share by the elasticity of unemployment with respect to the output gap, which Girouard and André estimate to -7.9 for Denmark.

As noted in the main text, we arrive at an output elasticity of net tax revenues of 2.09.

Appendix C: Computing Variance Decompositions

To perform the variance decompositions, we rely on results from spectral analysis. Recall that any covariance-stationary time series can be represented equally well in the frequency domain as in the time domain (Hamilton, 1994). In the frequency domain, the spectral density of the process is a measure of the share of the overall variance of the process accounted for at various frequencies. If the spectral density is high at low frequencies, much of the variation of the process can be interpreted as long-term movements in the data, perhaps reflecting an underlying trend.

For our VAR-model outlined in section 2, the spectral density of X_t at any frequency ω is given by:[15]

$$S_X(\omega) = \left[I - A\left(e^{-i\omega}\right)\right]^{-1} CC' \left[I - A\left(e^{-i\omega}\right)'\right]^{-1} \tag{C.1}$$

Here, A is the coefficient matrix from the VAR regression, and I is the identity matrix. C is the matrix linking the reduced-form residuals of the VAR-regression to the structural shocks of the model, with the property $CC' = V$, as described in subsection 2.2. i denotes complex i, so that $i^2 = -1$. Thus, the function assigns to any frequency ω a square matrix of complex numbers. However, as pointed out in Hamilton (1994), the complex part of the diagonal elements in this matrix will in fact be zero. The spectral density at frequency ω for each of the variables in Y_t is given exactly by these (real and non-negative) diagonal elements of the matrix.

We want to compute the variance of each of the variables in X_t that is accounted for by each of the shocks in ε_t. Recall that in the expression for the spectral density, $CC' = V$ denotes the variance-covariance matrix when all the shocks are 'turned on'. Following Altig *et al.* (2005), in order to compute the spectral density of X_t when only the j'th shock $(j = 1, .., 4)$ is turned on, we can replace CC' by CI_jC', where I_j is a square matrix of zeros, except for a unit entry in the j'th diagonal element. In other words,

$$S_X^j(\omega) = \left[I - A\left(e^{-i\omega}\right)\right]^{-1} CI_jC' \left[I - A\left(e^{-i\omega}\right)'\right]^{-1} \tag{C.2}$$

denotes the spectral density of X_t when only shock j is active.

As the spectral density for variable k is given by the k'th diagonal element of $S_X(\omega)$, we can then compute the fraction of the variance of the k'th variable accounted for by the j'th shock at frequency ω as:

$$var_{k,j}(\omega) = \frac{\left[S_X^j(\omega)\right]_{kk}}{\left[S_X(\omega)\right]_{kk}} \tag{C.3}$$

- where $[M]_{kk}$ denotes element (k,k) of matrix M. Observe that by construction:

[15] See Hamilton (1994) or Altig *et al.* (2005).

$$\sum_{j=1}^{4} var_{k,j}\left(\omega\right) = 1 \tag{C.4}$$

Having decomposed the variance of any variable at any frequency, we can then sum the variance ratios over various frequency bands, for example the business cycle frequencies, and see how important each shock is for each variable within these frequency bands.