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Financial structures and the real effects of credit-supply shocks in Denmark 1922-2011[1]

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Abstract

We examine the real effects of credit-supply shocks using a series of structural vector autoregressive models estimated on the basis on a new quarterly data set for Denmark spanning the past 90 years or so. We find no effects on the unemployment level from supply-shocks to credit from commercial/savings banks in the periods 1922-1949 and 1981-2011 even though these periods contained several cases of severe banking and financial crises. Furthermore, credit-supply shocks do not seem to explain any significant share of the volatility in the unemployment rate during these periods. We attribute these findings to the large market for mortgage-credit loans in Denmark raised through bond-financed mortgage banks combined with comprehensive government interventions to safeguard financial stability during times of crises. There might, however, be indications of real effects from credit-supply shocks in the period 1950-1980 where credit rationing and exchange controls served as important economic-policy instruments. Overall these results indicate that both the financial-system structure as well as the extent of government intervention during banking crises play a key role to the significance of real effects of credit-supply shocks. These findings must be kept in mind when modelling the role of financial intermediaries in macroeconomic models.

Key words: Credit-supply shocks; Banking and financial crises; Vector autoregressions; Danish Economic history.
JEL Classification: C32; E51; N14.

Resumé (Danish summary)

Vi belyser de realøkonomiske effekter af udbudsstød til kreditgivningen via en række strukturelle vektorautoregressive modeller på basis af nye kvartalsdata for Danmark, som dækker de seneste knap 90 år. Vi finder ingen indikationer på realøkonomiske effekter af udbudsstød til pengeinstitutternes kreditgivning i årene 1922-1949 og 1981-2011, selv om disse perioder omfatter flere tilfælde af alvorlige bank- og finanskriser. Vi tilskriver dette resultatet til det store marked for realkreditlån i Danmark optaget via obligationsudstedende realkreditinstitutter kombineret med omfattende offentlige støtteindgreb til sikring af den finansielle stabilitet i kriseperioder. Der er dog muligvis indikationer på realøkonomiske effekter fra udbudsstød til kreditgivningen i perioden 1950-1980, hvor kreditrationering og valutakontrol udgjorde vigtige økonomisk-politiske instrumenter. Samlet indikerer disse resultater, at såvel den finansielle struktur som omfanget af offentlige støtteindgreb i forbindelse med bankkriser spiller en vigtig rolle for de realøkonomiske effekter af udbudsstød til kreditgivningen. Disse forhold må holdes for øje ved modellering af banksektoren i forbindelse med makroøkonomiske modeller.

1. Introduction

In the wake of the international financial crises 2008/2009, there has been a renewed research interest in the linkages between the financial sector and the real economy. One of the topical issues is the real effect of credit-supply shocks, i.e. shocks that can affect the ability and willingness of monetary and financial institutions to supply credit to non-financial firms and households.

In an economic downturn, credit demand usually declines due to the decline in economic activity. Furthermore, the creditworthiness of the borrowers deteriorates during a recession, which leads banks to tighten their credit standards and reduce their lending activities in response to the declining repayment capability of the borrowers. However, a negative credit-supply shock during a recession – i.e. a tightening of the banks' lending standards by considerably more than the weak economic development normally would warrant – might reinforce the slowdown of the economy if creditworthy firms or households cannot obtain sufficient financing. In a similar way might a positive credit-supply shock during an upturn – i.e. a decline in the banks' lending standards by considerably more than the strong economic development normally would imply – stimulate consumption and investment and thereby reinforce the boom in the economy.

Empirical macroeconometric studies making an attempt to trace such real effects of credit-supply shocks could benefit considerably from access to long-span consistent time series of a range of key economic indicators at a monthly or quarterly frequency. Data sets spanning over periods characterised by different economic-policy regimes, other differences in the institutional setting and differences in the rate of real or monetary shocks to the economy could serve as the basis for robustness checks in empirical investigations of credit-supply shocks. However, such data sets are usually hard to obtain, and researchers often have to rely on either long-span annual time series or monthly/quarterly data covering only the most recent decades.

The paper at hand examines the real effects of credit-supply shocks using a series of structural vector autoregressive (VAR) models estimated on the basis on a new quarterly data set for Denmark spanning the past 90 years or so. We find no evidence of real effects from credit-supply shocks in the periods 1922-1949 and 1981-2011 even though these periods contained several cases of severe banking and financial crises. We attribute this finding to the large market for mortgage-credit loans in Denmark raised through bond-financed mortgage banks combined with comprehensive government interventions to safeguard financial stability during times of crises. There might, however, be indications of real effects from credit-supply shocks in the period 1950-1980 where credit rationing and exchange controls served as important economic-policy instruments. Overall these results indicate that both the financial-

system structure as well as the extent of government intervention during banking crises play a key role to the significance of real effects of credit-supply shocks.

2. A brief review of related literature

The paper relates most closely to the strand of the macroeconometric VAR literature that focuses on identification of credit-supply shocks and measurement of the effects on the real economy of such shocks. Recent studies include Halvorsen and Jacobsen (2009), Busch *et al*. (2010), Bassett *et al*. (2010), Hristov *et al*. (2011) and Helbling *et al*. (2011).

Halvorsen and Jacobsen (2009) estimate linear structural VAR models for the UK and Norway based on quarterly data 1988-2009 on the following 6 variables: The short-term interest rate, inflation, the output gap, real house prices, the real exchange rate and the ratio between bank lending and other financing to non-financial firms and households. Using sign and short-term zero restrictions they find that a negative shock to bank lending has a negative impact on the output gap, particularly in periods with widespread banking failures.

Busch *et al*. (2010) explore a quarterly German data set 1991-2009 comprising the real GDP, CPI, the overnight interest rate, the nominal value of loans to non-financial corporations, the interest rate on such loans and the yield-spread between corporate and government bonds. Using Bayesian linear vector autoregressive models with sign restrictions on the impulse response functions they find a very persistent negative output effect from a negative loan supply shocks. Furthermore, they identify strong negative loan supply shocks in the quarters following the collapse of Lehman in 2008.

Bassett *et al*. (2010) uses the Federal Reserve's quarterly Senior Loan Officer Opinion Survey to create a quarterly measure of credit supply shocks 1992-2010. They include this measure as an exogenous variable in a linear reduced-form VAR model with real GDP growth, inflation, growth in bank lending capacity (the sum of loans to businesses and households and unused commitments), a credit spread and the federal funds rate as endogenous variables. Their analysis shows large effects on real GDP of shocks to changes in lending standards.

Hristov *et al*. (2011) estimate a panel VAR model on the basis of a quarterly data set 2003-2010 comprising the following 5 variables for 11 member states in the Euro Area: Real GDP, the GDP deflator, the nominal short-term interest rate, the loan rate and the loan volume. Using sign restrictions they find that loan-supply shocks contributed significantly to the decline in real GDP during the recent financial crisis.

A more global perspective is offered by Helbling *et al*. (2011). They examine the importance of credit shocks in driving the business cycles in G7 and the US over the period 1988-2009. The data set consists of quarterly time series on credit to the private sector from

domestic deposit-taking banks, real GDP, labour productivity, inflation and interest rates in the G-7 countries. Furthermore US credit spreads and default rates are included. Using sign restrictions imposed on impulse response their VAR analysis suggests that credit shocks played an important role in driving economic activity during the global recessions 1990-1991 and 2007-2009.

The paper at hand adds to this strand of the literature by analysing the real effects of credit-supply shocks based on a quarterly data set constructed by the author covering a time-span of almost 90 years. This is a considerably longer sample period than previously found in the VAR-based literature on credit-supply shocks. The long data set makes it possible to assess the role played by credit shocks in the Danish economy in connection with the recent financial crisis since 2008, the banking crisis during the long recession 1987-1993 and the severe banking crisis 1920-1933.

3. Data description

For the analysis in this paper we compiled a data set comprising 7 key quarterly macroeconomic indicators on the Danish economy covering the period 1922q3-2011q3.

The data set contains two blocks of variables. The block of real economic indicators consists of the unemployment rate and the consumer price index. Naturally, it would have been preferable if real GDP were available as an indicator of real economic activity, but quarterly national accounts are only available for Denmark for the entire sample period. However, as part of the robustness checks in our credit-supply-shock analysis in section 7 we also use respectively real GDP and the industrial production index as indicators of real economic activity instead of the unemployment rate in a quarterly data set covering the period since 1950.

The block of monetary and financial indicators consists of the short-term interest rate, the long-term interest rate, the share price index, the stock of broad money (M2) and a credit-mix variable. The credit mix is defined as credit to the domestic non-bank sector extended by resident commercial/savings banks in per cent of credit to the domestic non-bank sector extended by resident commercial/savings banks and mortgage banks. All the series in this block are based on nominal values.

The long-term interest rate is the yield on long-term central-government bonds, and the short-term interest rate is the official discount rate of Danmarks Nationalbank (the central bank of Denmark). It should be noted that for long periods the discount rate has not been directly related to any of Danmarks Nationalbank's monetary-policy instruments. However, for most of the period since 1922 the discount rate has been a good indicator for the general

development in short-term interest rates in Denmark, cf. Abildgren (2005). More details on the credit-mix variable are given in section 4.

A number of adjustments have been made in order to transform the background data into a set of fairly consistent indicators. The adjustments relate mainly to breaks in series due to e.g. changes in compilation methods and statistical classifications *etc*. in the primary statistical sources from which the indicators are drawn. In most cases adjustments for these breaks were made by chained together old and new series.

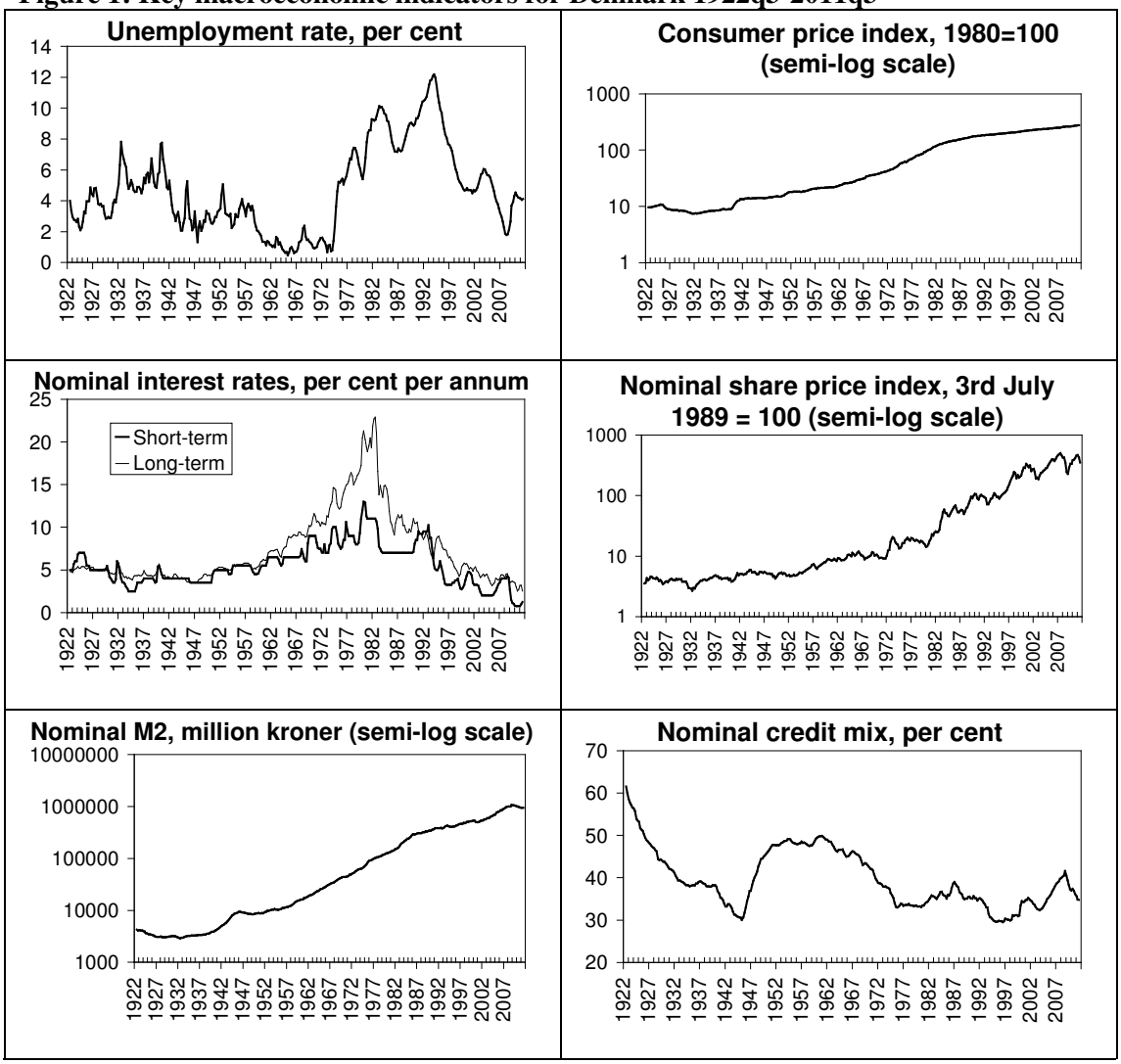
Table 1: Data sources and data constructions

Time series	Notes	Sources
Real economic indicators		
Unemployment rate	Unemployed persons in per cent of the total labour force. Quarterly averages. Quarterly data prior to 1932q1 for unemployment among non-members of unemployment insurance funds has been interpolated from annual data. Adjusted for various breaks in series.	Pedersen (1977); Statistics Denmark (1996); Topp (1997, 2008); Statistics Denmark, *Statistical Yearbook*, various issues; Statistics Denmark, *Statistical ten-year review*, various issues; Statistics Denmark, *Konjunkturstatistik*, various issues; and Statistics Denmark's website.
Consumer price index (CPI)	1980=100. Quarterly averages. Prior to 1927q1 interpolated from semi-annual data. Adjusted for various breaks in series.	Abildgren (2012); Statistics Denmark, *Statistical Yearbook*, various issues; and Danmarks Nationalbank's website.
Monetary and financial indicators		
Short-term interest rate	Official discount rate of Danmarks Nationalbank. Per cent per annum. Quarterly averages.	Mordhorst (1968); Abildgren (2012) and Danmarks Nationalbank's website.
Long-term interest rate	Yield on long-term Danish government bonds. Per cent per annum. Prior to 1983q3: Yield to maturity on long central government bonds. Since 1983q3: Yield to maturity on 10-year central government bonds. Prior to 1960: The quarterly figures refer to 15 March, 15 June, 15 September and 15 December. Since 1960: Quarterly averages of daily observations.	Abildgren (2012); Hansen (1969); and Danmarks Nationalbank's website.
Share price index	3rd July 1989 = 100. End of quarter. Prior to 1994: Covers all shares at the Copenhagen Stock Exchange. Since 1994: OMXC20 (KFX). Adjusted for various breaks in series.	Abildgren (2012); Statistics Denmark, *Statistiske Efterretninger*, various issues; Statistics Denmark, *Statistical Yearbook*, various issues; and Danmarks Nationalbank's website.
Broad money stock (M2)	Million kroner. End of quarter. Deposits in savings banks are not available on a quarterly basis prior to 1928q4 and have therefore for this period been interpolated (geometrically) from annual figures. Adjusted for various breaks in series.	Abildgren (2012); Danmarks Nationalbank, *Report and Accounts*, various issues; Statistics Denmark, *Statistiske Efterretninger*, various issues; and Danmarks Nationalbank's website.
Credit mix	Credit to the domestic non-bank sector extended by resident commercial/savings banks in per cent of credit to the domestic non-bank sector extended by resident commercial/savings banks and mortgage banks. End of quarter. Credit from savings banks is not available on a quarterly basis prior to 1943q3 and has therefore been interpolated (geometrically) from annual figures. For the period 1928q2-1980q4 has the outstanding amount of credit from mortgage banks been calculated on the basis of accumulated flow-of-funds. Credit from mortgage banks is not available on a quarterly basis prior to 1928q1 and has therefore been interpolated (geometrically) from annual figures. Adjusted for various breaks in series (including the expansion of the population of reporting commercial banks with FIH (Finance for Danish Industry) in the first quarter of 2003).	Abildgren (2012); Jeppesen (1969); Danmarks Nationalbank, *Report and Accounts*, various issues; Statistics Denmark, *Statistical Yearbook*, various issues; Statistics Denmark, Statistiske Efterretninger, various issues; and Danmarks Nationalbank's website.

In a few areas complete quarterly information was not available for the whole sample period. In these areas missing quarterly observations were interpolated from semi-annual or annual data, cf. Table 1 for further details.

Finally it should be mentioned that all the series in the data set except interest rates and the share price index has been seasonally adjusted via X-12-ARIMA, cf. U.S. Census Bureau (2009).

Figure 1: Key macroeconomic indicators for Denmark 1922q3-2011q3



Notes: All the series except interest rates and the share price index have been seasonally adjusted via X-12-ARIMA.
Sources: See Table 1.

The seven indicators in the data set are shown in Figure 1.[2] A few more detailed remarks should be given regarding the level of the unemployment rate in Denmark in the 1930s, which have been subject to intensive debate in the literature. The contemporary official records for

[2] This data set is available in electronic form on request from the author.

the "headline" unemployment rate in the 1930s covered only unemployment among members of unemployment insurance funds and showed unemployment rates (measured relative to the total numbers of members of unemployment funds) around 30 per cent in 1932-1933, cf. Table 2. However, only around one third of the Danish workers were members of an unemployment insurance fund in 1930, cf. Topp (2008). Recent research on unemployment in Denmark in the 1930s suggest that the level of unemployment in 1932-1933 was much lower than 30 per cent if one follows modern definitions of the unemployment rate covering unemployment among members as well as non-members of unemployment insurance funds (measured relative to the total labour force), cf. Pedersen (1977), Christensen (2002) and Topp (1997, 2008). Statistics Denmark (1996) has also retrospectively recalculated the unemployment figures for the years 1937-1939 following modern definitions and found substantial lower levels of unemployment rates than suggested in contemporary statistics from the 1930s. The unemployment figures compiled in the study at hand are quite close to the figures found in Pedersen (1977) and Statistics Denmark (1996).

Table 2: Unemployment rates in Denmark in the 1930s

	Unemployment rate among members of unemployment insurance funds in per cent of the total number of members of unemployment funds	Total unemployment rate (unemployment among members and non-members of unemployment insurance funds in per cent of the total labour force)				
	Official contemporary statistics from the 1930s	Statistics Denmark (1996)	Pedersen (1977)	Christensen (2002)	Topp (1997, 2008)	This Study
1930	...	...	2.9	5.1	3.0	3.0
1931	17.9	...	3.7	6.2	4.1	4.1
1932	31.7	...	6.7	9.5	7.5	6.4
1933	28.8	...	6.5	9.1	7.3	6.2
1934	22.2	...	5.4	7.4	5.9	5.0
1935	19.7	...	5.0	6.6	5.3	4.7
1936	19.1	...	5.2	6.5	5.3	4.8
1937	21.7	5.6	6.1	7.3	6.1	5.5
1938	21.3	5.7	6.2	7.3	6.1	5.8
1939	18.4	5.2	5.5	...	5.5	5.2

Notes: Annual averages.

In Figure 1 one might note that the short-term volatility in the unemployment figures seems to be relatively high in the period until the early 1970s compared to the post-1970 period. This might be related to data issues but could also reflect the structural transformation of the economy towards increased production of services as well as an increase over time in the unemployment compensation ratio (i.e. unemployment benefits relative to wage), cf. Abildgren (2009b, 2012).

4. Credit-supply shocks – identification strategy

Since credit aggregates are determined jointly by supply and demand, a crucial challenge in macroeconometric studies of credit-supply shocks is to isolate credit-supply shocks from credit-demand shocks. If the economy is struck by a negative shock both output and credit will usually decline. It is therefore difficult to identify whether the decline in credit reflects a reduction in credit supply or a fall in credit demand, cf. Bernanke and Gertler (1995) and Oliner and Rudebusch (1996).

Kashyap *et al*. (1993, 1996) argue for the use of a financing mix variable (the ratio between bank credit and total credit) to obtain a clearer econometric identification of credit-supply shocks. The concrete empirical proxy for the financing mix used in Kashyap *et al*. (1993) is the ratio between bank credit and the sum of bank credit and commercial papers. Commercial papers are usually believed to be the closest low-cost substitute for unsecured bank loans in the financing of non-financial firms in the US. More recently have e.g. Halvorsen and Jacobsen (2009) used a credit-mix variable (bank credit to households and firms relative to total credit to households and firms) in a VAR analysis of lending shocks in Norway and the UK.

In the paper at hand we define the credit-mix variable as credit to the domestic non-bank sector extended by resident commercial/savings banks in per cent of credit to the domestic non-bank sector extended by resident commercial/savings banks and mortgage banks. Credit from mortgage banks is the closest and most important alternative low-cost source of secured financing for the private non-financial sector in Denmark.

The basic idea behind the credit-mix approach in this paper is that a general change in the demand for credit all else equals will change the demand for credit from the deposit-financed commercial/savings banks and the bond-financed mortgage banks in equal proportions and thereby not alter the credit mix. A change in credit from commercial/savings banks relative to credit from mortgage banks would imply a change in the credit mix variable. If this change is considerably larger than normal – conditional on the economic development – it can be interpreted as positive or negative supply shocks to credit from either commercial/savings banks or mortgage banks. However, as we argue below the special role played by mortgage banks in the Danish financial system makes supply shocks to credit from mortgage banks improbable unless there are changes in the legal and operational framework for mortgage banks. Exogenous shocks to the credit-mix variable will therefore normally reflect supply shocks to credit from commercial/savings banks.

Mortgage banks have played a very important credit-supplying role in the Danish economy for the past one and a half century, cf. Frankel et al. (2004), Abildgren (2008) and Andersen (2011). In 1923 credit to the domestic non-bank sector extended by resident mortgage banks

corresponded to around 75 per cent of credit to the domestic non-bank sector extended by resident commercial/savings banks. In 2010 the share was around 170 per cent.

Mortgage banks offer credit secured by mortgage on real property financed by the issuance of exchange-quoted bonds. The Danish market for mortgage bonds dates back to the late 18th century, and the expansion of the mortgage-credit system for the financing of real property in Denmark after 1850 laid the foundation for the development of a large and liquid market for mortgage bonds. Today, the Danish mortgage bond market is one of the largest in Europe, only surpassed by Germany, cf. Association of Danish Mortgage Banks (2009), and even during the international financial crisis 2008-2010 Danish mortgage bonds were just as liquid as Danish government bonds, cf. Buchholst *et al*. (2010).

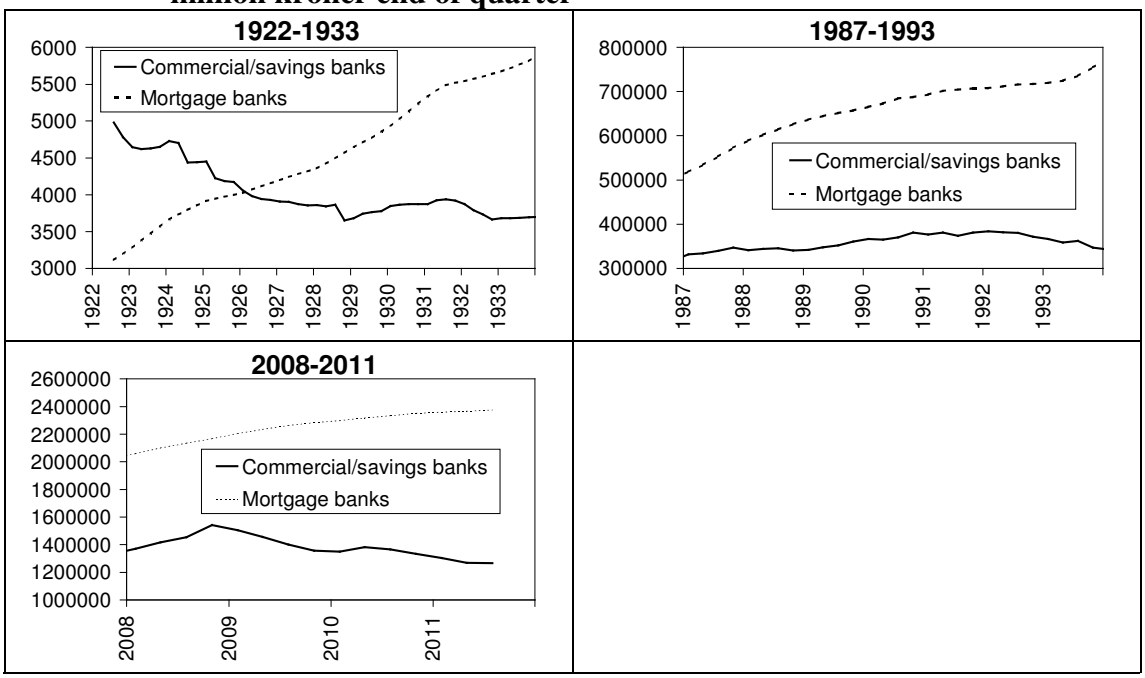
The Danish mortgage banks have to a very high degree to comply with the so-called "balance principle" requiring a balance between the payments received from the borrower on an individual loan and the payments made to the bondholders via the bonds financing the loan (i.e. Danish mortgage bonds are "pass-through securities"). This implies that the assets and liabilities of a mortgage bank are matched in terms of interest rates and maturity. The debtor can terminate most loans granted by mortgage banks at par. In the case of early redemption, the bonds financing the loan are called at par by the mortgage bank whereby the balance principle is ensured. Due to these special characteristics the market risk is not absorbed by the mortgage banks but traded in the market between the borrowers and the bond investors. Furthermore, the use of collateral implies that the level of write downs ("provisions" or "loan impairment charges") relative to outstanding loans are usually very low, and only limited price-discrimination is made between borrowers with different credit risks, cf. Gundersen *et al.* (2011). This makes it reasonable to assume that supply shocks to credit from mortgage banks is normally not an issue, cf. also Pedersen (2003). Following this line of reasoning exogenous shocks to the credit mix variable will normally reflect supply shocks to credit from commercial/savings banks.

However, changes in the legal and operational framework for the mortgage banks might be mentioned as possible sources to supply shocks to credit from mortgage banks. Supply shocks to credit from mortgage banks might for instance have occurred during the years 1965-1971 where loan offers from the mortgage banks were subject to a quota system imposed by the monetary authorities. In such periods exogenous shocks to the credit mix variable can either reflect supply shocks to credit from commercial/savings banks or to credit from mortgage banks.

There was a clear decline in the credit-mix variable in the periods 1922-1933, 1987-1993 and 2008-2011, which all was characterised by several failures among commercial banks and savings banks. The decline in the credit mix during these periods was the result of an

increasing trend in credit from mortgage banks and a declining or stagnating trend in credit from commercial/savings banks, cf. Figure 2. In these three periods where many commercial/savings banks were in financial distress there thus seems to have been a relative substitution from credit from commercial/savings banks towards credit from mortgage banks. During these periods it seems most likely to assume that exogenous shocks to the credit mix, if any, reflect supply shocks to credit from commercial/savings banks.

Figure 2: Credit to the domestic non-bank sector extended by resident banks, million kroner end of quarter



Notes: All the series have been seasonally adjusted via X-12-ARIMA.
Source: See Table 1.

However, there has also to have been a decline in the credit mix in other periods and in general there seems to have been a long-term downward trend in the credit-mix variable, cf. Figure 1. The aim of the analysis in this paper is to identify whether there has been periods with exogenous shocks to the credit mix – i.e. changes in the credit mix that can not be explained with the general economic development (cycle or trend) – and if so whether such shocks have had a significant influence on the unemployment rate.

5. Econometric approach and model specification

A VAR model is a system of linear equations where each of the endogenous variables is explained as a linear function of its own lagged values and the lagged values of all the other variables in the system. It is thus a very simple type of model, which is nevertheless able to

capture the often rich and complicated dynamic interactions between a range of macroeconomic time series.

VAR models were introduced by Sims (1972, 1980a, 1980b) and have found extensive use in relation to studies on monetary transmission. Since the dynamic interactions between the financial sector and the real economy are rich and complicated, a VAR approach seems particularly useful for empirical studies of the role of the banking systems in the macroeconomy due to the few *a priori* restrictions and limited structure imposed on such models. In the recent decade or so VAR models have also been found useful in relation to analysis of financial stability issues, and we apply therefore a standard VAR approach in this paper.

Based on the data set from section 3 we estimate a structural VAR model where we rely on a Cholesky decomposition to identify the structural shocks, cf. appendix 1.[3] The standard VAR model used in the literature for analysing monetary transmission usually includes three endogenous variables: An indicator of real economic activity, prices, and the short-term interest rate. We use the unemployment rate as an indicator of real economic activity, the CPI as prices, and the Nationalbank's discount rate as the short-term interest rate. In addition to these three variables we include four more endogenous variables (the yield on long-term central-government bonds, share prices, M2 and the credit mix) commonly known to be of interest in relation to the interactions between the real and the financial side of the economy. Following the argument of Sims *et al*. (1990), we estimate our VAR in levels, and we include constant terms and linear time trends, cf. Table 3.

In the VAR model, the monetary and financial block of variables is placed after the block of variables describing the real economy. This ordering allows the monetary and financial variables to respond immediately to shocks to the real side of the economy. Furthermore, since credit mix has been placed last in the ordering, the estimated effects from a structural shock to the credit mix are to the widest possible extent "cleaned" from movements in and shocks to the other variables in the system. The model has thus the most "conservative" ordering of the endogenous variables in relation to tracing real effects from credit-supply shocks. On the other hand this implies that there is a stronger case for the existence of real effects from credit-supply shocks if these can be traced in the model.

[3] The econometrics of VAR models and impulse-response analysis is e.g. covered by Hamilton (1994) and Krätzig and Lütkepohl (eds.) (2004). All econometric results presented in the paper at hand have been obtained via the use of PCGive and JMulTi.

Table 3: Specification of the VAR model

Endogenous variables listed in order		1. Unemployment rate (level) 2. CPI (log-level) 3. Short-term interest rate (level) 4. Long-term interest rate (level) 5. Share price index (log-level) 6. M2 (log-level) 7. Credit mix (level)
Deterministic terms		Constant terms Linear time trends
Optimal endogenous lags indicated by the	Akaike Information Criterion	3
	Hannan-Quinn Criterion	2
	Schwarz Criterion	2
Chosen number of endogenous lags		4
LM tests for autocorrelation (a) (p-values in brackets)		1.1598 (0.0725)

(a) Up to the chosen number of lags in the model. Vector tests in F-form. Null hypothesis is no autocorrelation.

The number of lags in the VAR-model has been guided by various information criteria. However, the chosen number of lags has been determined to ensure no serious signs of autocorrelation in the residuals measured by vector diagnostics. The relatively high number of lags needed in order to eliminate signs of autocorrelation might be related to the use of seasonally adjusted data.

6. Robustness checks

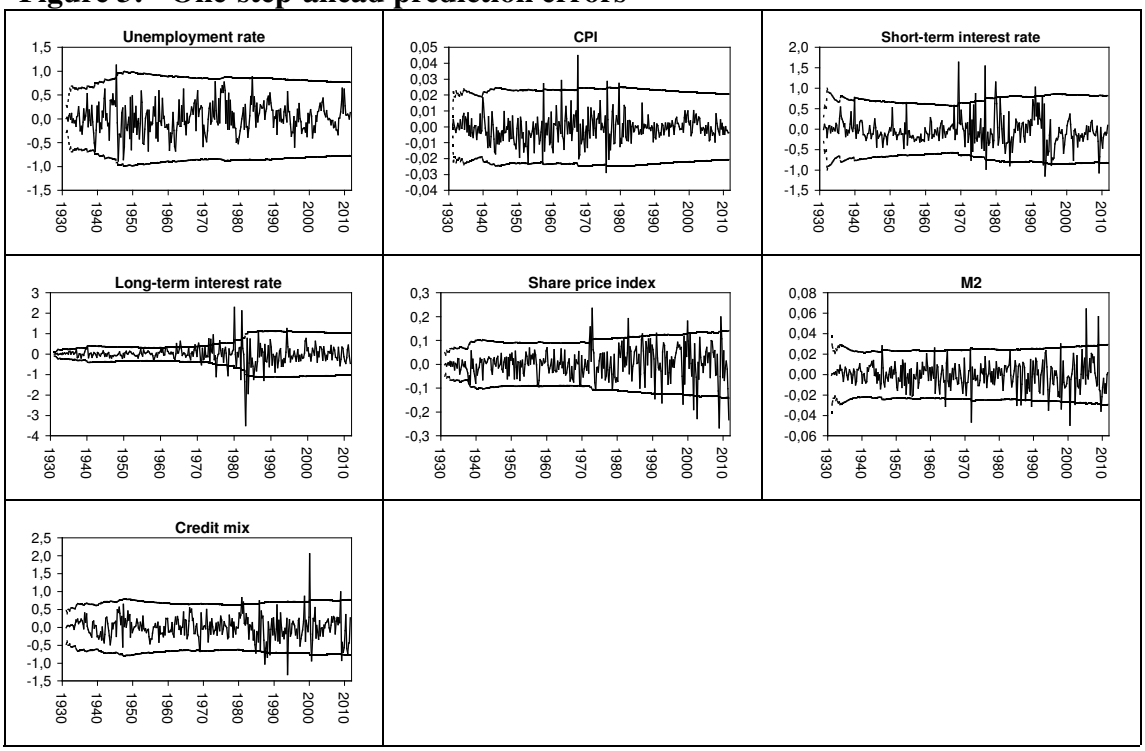
6.1 Recursive residuals

Figure 3 shows the one-step-ahead prediction errors (also known as "one-step recursive residuals") for the seven equations in the VAR model. The figure illustrates how the one-quarter-ahead forecast error in each equation changes when new observations are added recursively to the estimation sample. Residuals outside the standard error bands can be taken as an indicator of outliers or parameter instability.

For all the equations in the model most prediction errors stay inside the 95 per cent confidence bounds. Overall the prediction errors do not indicate signs of structural change or parameter instability although some outliers seem to be present.

However, one might note a change in the volatility of the prediction errors around 1980 for several of the equations in the model. In our analysis of credit-supply shocks in section 7 we therefore estimate the VAR models for three separate sub-periods (1922q1-1949q4, 1950q1-1980q4 and 1981q1-2011q3).

Figure 3: One-step-ahead prediction errors



Notes: Dashed lines indicate +/- two standard deviations. 10 observations have been used for initialisation.

6.2 Responses to a shock to the short-term interest rate

The responses to a exogenous shock to the short-term interest rate within the framework of VAR models have been studied intensively in the literature and is therefore suitable as a robustness check of the estimated VAR model, cf. Figures 4.

The shape and direction of the responses to a shock to the short-term interest rate seem in general to be in line with the existing literature. After the shock the short-term interest rate gradually converges back to the baseline level. The long-term interest rate rises significantly following the shock but less than the increase in the short-term interest rate. The pattern of the long-term interest rate is consistent with the expectation theory of the term structure, according to which the long-term interest rate is an average of the expected future short-term interest rates (plus a risk premium).

Share prices drop significantly during the first couple of years after the interest-rate shock before they begin a reversion towards the baseline level. This is in line with a discounted dividend model for share prices.

The unemployment rate increases after the interest-rate shock and reaches a maximum after a couple of years before a slow reverting back towards the baseline level begin. This reaction seems consistent with the line of reasoning in most mainstream macroeconomic models.

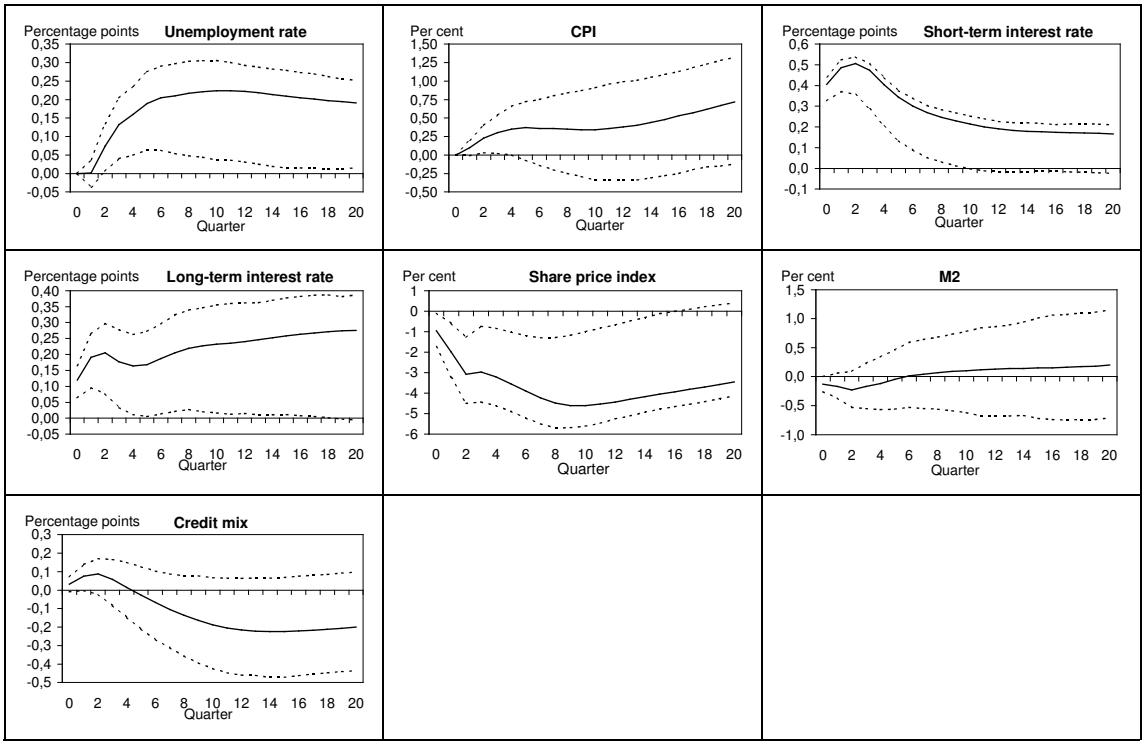
The response of the CPI seems not to be significantly different from zero after a couple of years. However, there might be traces of the so-called “price puzzle” known from the VAR

literature - cf. e.g. Christiano *et al.* (1999) - where an increase in the short-term interest rate is followed initially by an increase in the price level. The prize puzzle might reflect that the increase in the firm's interest costs to some degree is passed on to consumers.

There seems not to be any significant reaction of M2 to a shock to the short-term interest rate. This might reflect a combination of several factors. The higher short-term interest rate makes money more attractive which - all else being equal - should increase the demand for money. However, the increase in the long-term interest rate as well as a lower transaction level - indicated by the increase in the unemployment rate - reduces the demand for money.

Finally, there seems not to be any significant effect on the credit mix following the shock to the short-term interest rate. This is in line with *a priori* expectations. Even though the composition of credit from respectively commercial/savings banks and mortgage banks might differ with respect to duration, the credit mix should not be affected by a change in the short-term interest rate provided that the expectation theory of the term structure holds as indicated above.

Figure 4: Responses to a one standard error exogenous shock to the short-term interest rate



Notes: Dashed lines are 95 per cent confidence intervals calculated using bootstrap simulations with 1,000 trials. The orthogonalised impulse-response functions show deviations from the underlying baseline in per cent, except for interest rates, the unemployment rate and the credit mix, which show derivations from the baseline in percentage points.

6.3 Further Robustness checks

Since the identification of structural shocks in the analysis in this paper are based on a Cholesky decomposition the ordering of the endogenous variables might be an issue. As part of our robustness analysis we have therefore also estimated an alternative model, where the monetary and financial block of variables is placed before the block of variables describing the real economy. The responses to an exogenous shock to the short-term interest rate in the model with alternative ordering were very similar in direction, shape and magnitude to those shown in Figure 4.

At a 5 per cent significance level the result of Augmented Dickey Fuller (ADF) unit-root tests suggest that all the variables in levels are generated from non-stationary processes whereas all variables in differences are stationary.[4] As a robustness check on the order of integration of the endogenous variables we therefore also estimated the VAR model in first differences. However, judges by the estimated accumulated impulse-responses to an exogenous shock to the short-term interest rates the model in differences appeared to be less well specified than the model in levels.

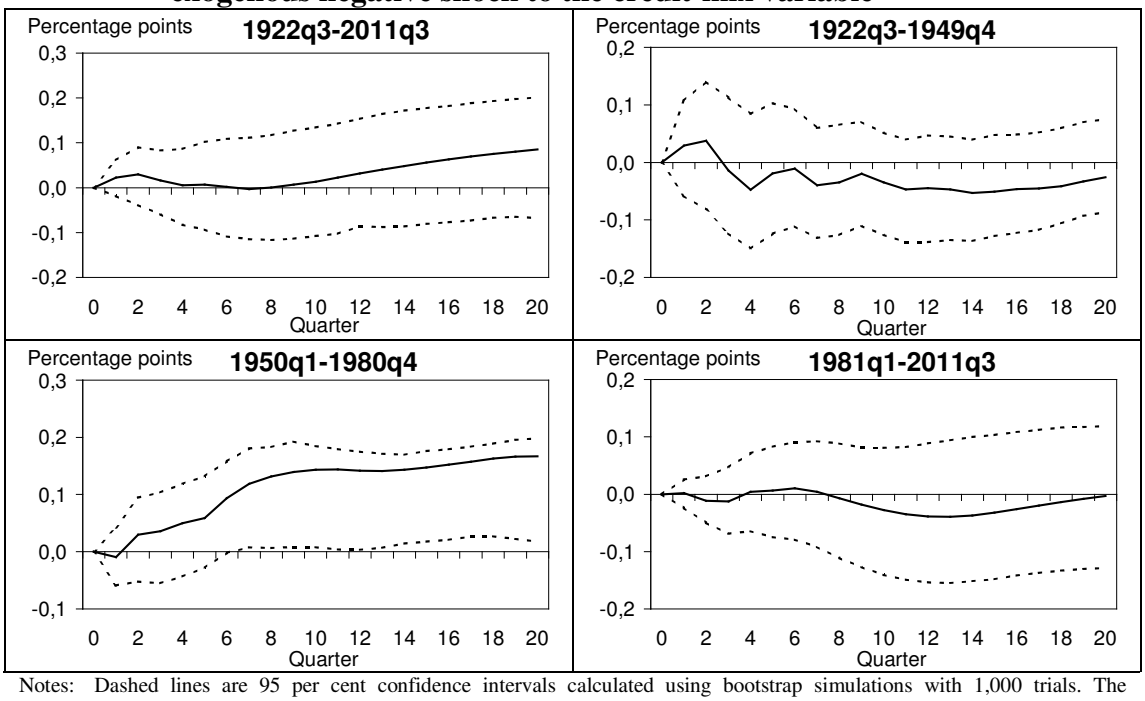
7. The real effects of credit-supply shocks

Figure 5 shows the estimated responses of the unemployment rate to an exogenous negative shock to the credit-mix variable in the VAR model from Table 4 estimated over the entire sample period 1922q3-2011q3 and three different sub-samples. Two of the sub-sample periods (1922-1949 and 1981-2011) include incidences of severe banking and financial crises whereas the period 1950-1980 was characterised by widespread financial stability.

We find no evidence of real effects from exogenous shocks to the credit mix in the periods 1922-1949 and 1981-2011. However, there might be a significant increase in the unemployment rate following an exogenous negative shock to the credit mix in the sub-sample 1950-1980.

[4] All tests included a constant, and for variables in levels a trend was included as well. ADF tests are known to be sensible to the choice of lag length for differences included in the test. The lag length in the tests was therefore been chosen with the aim of ensuring no significant signs of autocorrelation in the residuals at a 5 per cent significance level. It should be noted that the power of ADF tests against the null hypothesis of a unit root is known to be low.

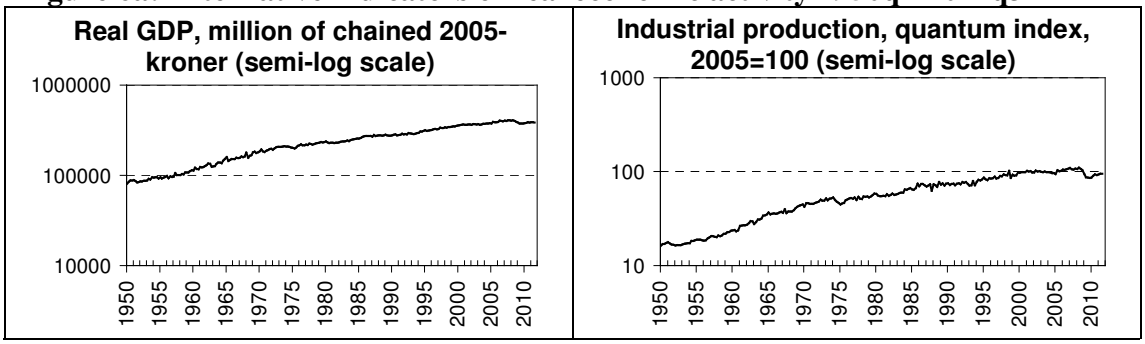
Figure 5: Responses of the unemployment rate to a one standard error exogenous negative shock to the credit-mix variable



Notes: Dashed lines are 95 per cent confidence intervals calculated using bootstrap simulations with 1,000 trials. The orthogonalised impulse-response functions show derivations from the baseline in percentage points.

As a robustness check we also estimated the VAR model from Table 4 for the post-1950 period using respectively real GDP and industrial production (quantum index) as indicators of real economic activity instead of the unemployment rate. The series enter into the model in log-levels and are shown in Figure 6a.

Figure 6a: Alternative indicators of real economic activity 1950q1-2011q3



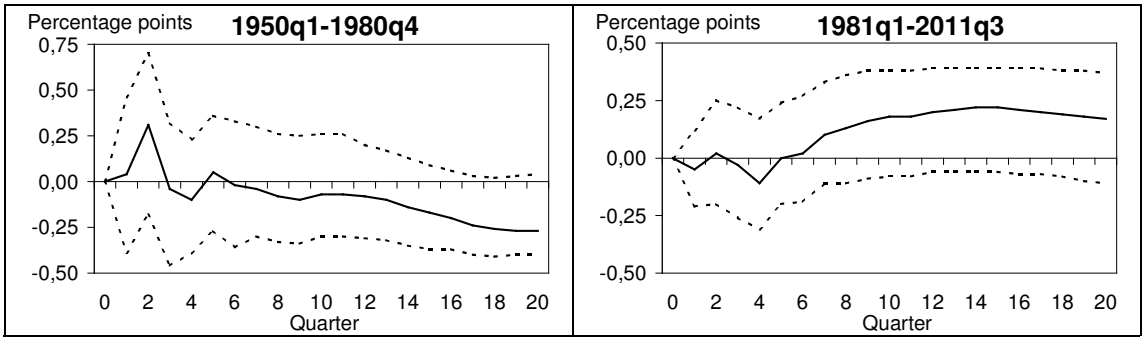
Notes: The series have been adjusted for various breaks by multiplicative chaining and have been seasonally adjusted via X-12-ARIMA.

Sources: Abildgren (2012), various publications from Statistics Denmark and Statistics Denmark's website.

Figure 6b shows the responses of real GDP to a negative exogenous shock to the credit mix. Here we dot not find any traces of real effects from credit-supply shocks, neither in the 1950-1980 period nor in the 1981-2011 period. When we use industrial production as an indicator

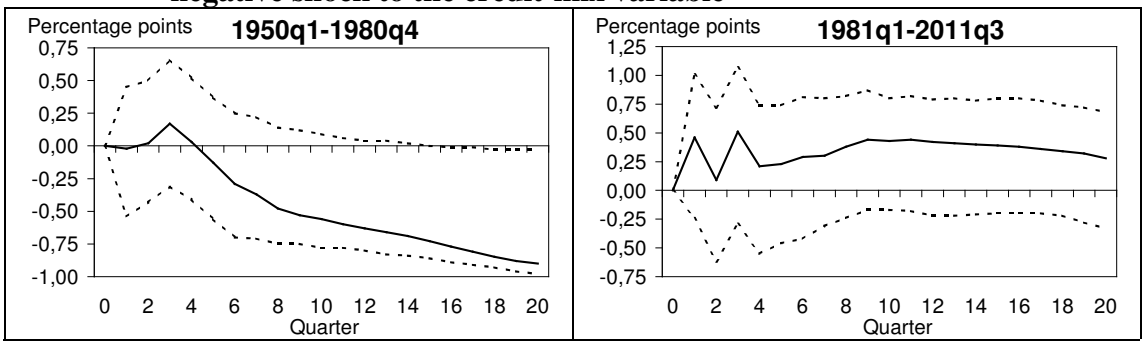
of economic activity we also find no indications of real effects from credit-supply shocks in the 1981-2011 period, but a slightly significant effect in the 1980-1980 period, cf. Figure 6c.

Figure 6b: Responses of real GDP to a one standard error exogenous negative shock to the credit-mix variable



Notes: Dashed lines are 95 per cent confidence intervals calculated using bootstrap simulations with 1,000 trials. The orthogonalised impulse-response functions show derivations from the baseline in per cent.

Figure 6c: Responses of industrial production to a one standard error exogenous negative shock to the credit-mix variable



Notes: Dashed lines are 95 per cent confidence intervals calculated using bootstrap simulations with 1,000 trials. The orthogonalised impulse-response functions show derivations from the baseline in per cent.

Except for the period 1950-1980 we thus find no indications of real effects of exogenous credit-supply shocks. We attribute these findings to two factors. First, during the entire period since 1922 there has been a large market for mortgage-credit loans in Denmark raised through bond-financed mortgage banks, cf. section 4. It seems therefore plausible that firms and households in the periods 1922-1949 and 1981-2011 were able to cover their borrowing requirement by shifting their financing pattern towards a higher degree of lending from mortgage banks at times when commercial banks and savings banks had to reduce their credit exposure, cf. also Figure 2 in section 4.

Second, during the severe banking crisis 1920-1933 the real effects of the banking crisis might have been moderated by extensive official interventions. The most significant case was Landmandsbanken, the largest bank in Scandinavia, which was reconstructed several times in the period 1922-1928 with help from the central bank and the central government. Also

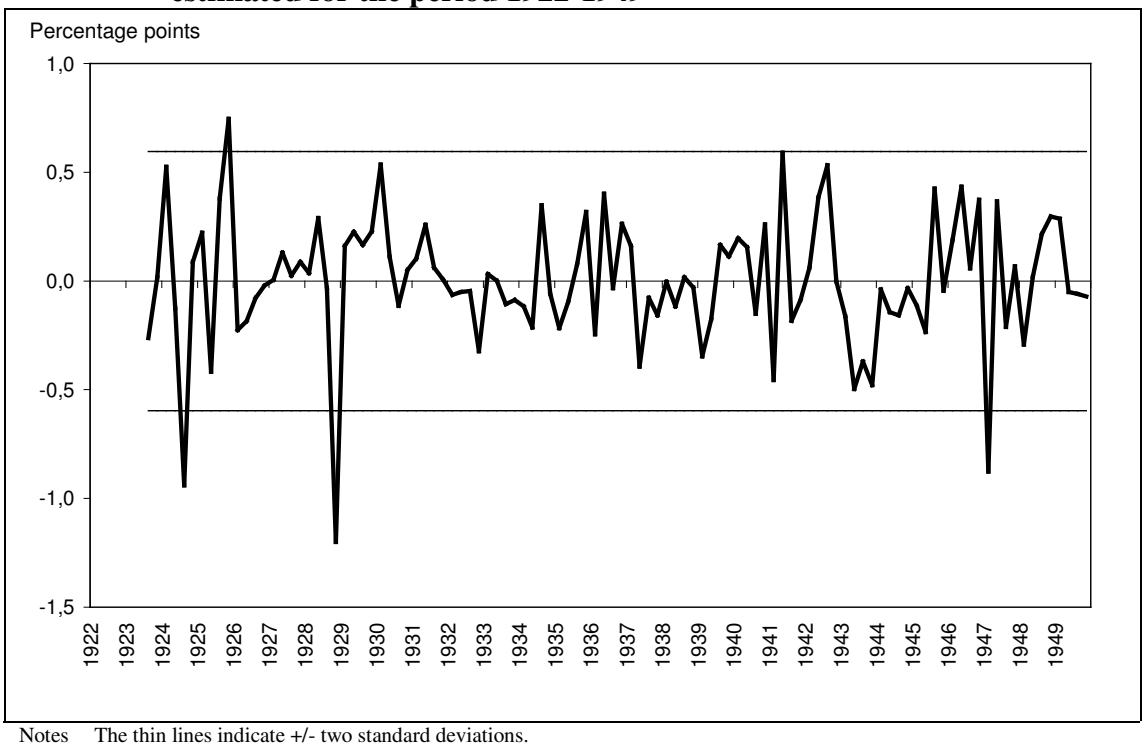
during the most recent financial crisis since 2008 the government and the central bank has implemented comprehensive support measures in favour of the financial sector in the form of guarantees, capital injections and emergency lending facilities. These support measures might help explain why no real effects from exogenous shocks to the credit mix seem to have occurred in the periods 1922-1949 and 1981-2011.

Figure 7a-7c shows the exogenous credit-supply shocks that historically have occurred according to the VAR model with unemployment as an indicator of economic activity estimated for three different sub-samples.

During the banking crisis 1920-1933 the write-downs (loan loss provisions) among commercial/savings banks totalled more than 20 per cent of loans and guaranties and all of the five main commercial banks ran into troubles, cf. Hansen (1996) for a thorough study of the course and causes of the crisis. There occurred two large exogenous negative shocks to the credit mix during the period 1922-1933, cf. Figure 7a.

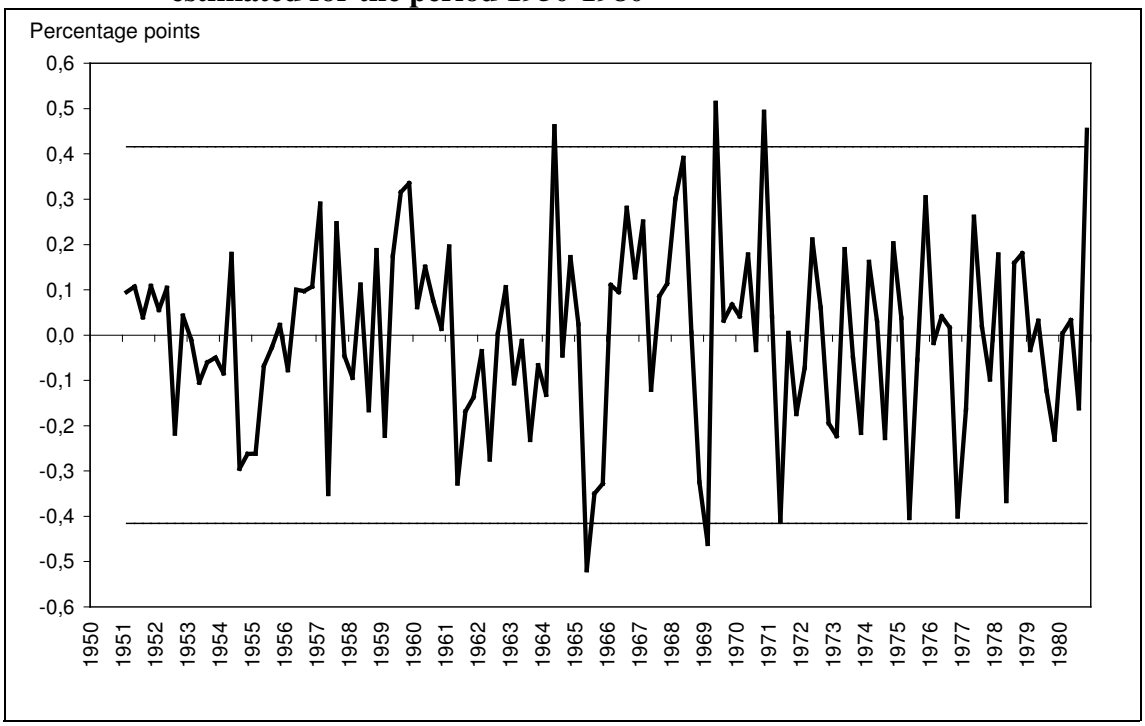
No clearly significant credit-supply shocks are visible in the post-1980 period despite several cases of bank failures in the late 1980s and early 1990s and again during the financial crisis since 2008, cf. Abildgren and Thomsen (2011). There is, however, a significant negative credit shock in 1985 after Denmark's 7th largest bank, Kronebanken, ran into problems, cf. Figure 7c. There is also a significant negative credit shock at the end of 1993 after the failure of Denmark's 9th largest bank, Varde Bank.

Figure 7a: Exogenous shocks to the credit mix identified in the VAR model estimated for the period 1922-1949



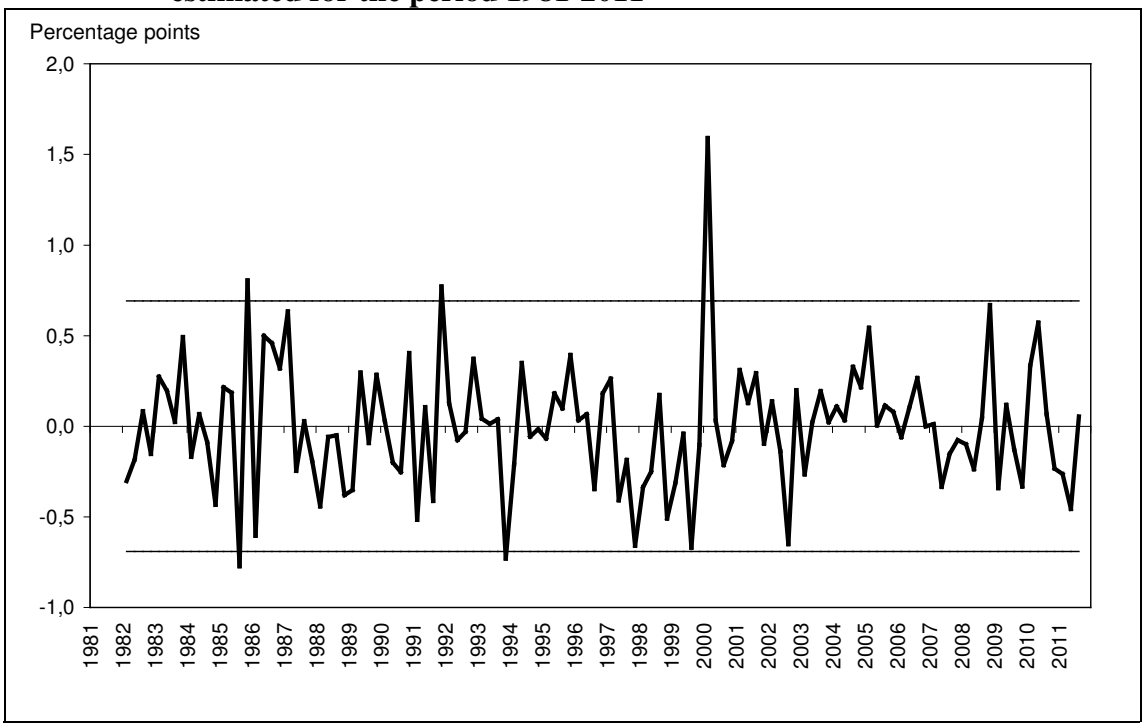
Notes The thin lines indicate +/- two standard deviations.

Figure 7b: Exogenous shocks to the credit mix identified in the VAR model estimated for the period 1950-1980



Notes: The thin lines indicate +/- two standard deviations.

Figure 7c: Exogenous shocks to the credit mix identified in the VAR model estimated for the period 1981-2011



Notes: The thin lines indicate +/- two standard deviations.

Figures 5 and 6c indicate that there might be significant real effects from credit-supply shocks in the sub-sample 1950-1980. During this period credit rationing and exchange controls served as important economic-policy instruments, cf. Blomgren-Hansen (1977) and Abildgren (2009a).

In the 1950s the Danish business sector was given access to obtain commercial credits related to imports and exports of goods and services, but prior to the restoration of current-account convertibility of the Danish krone in 1958 capital-account transactions were regulated tightly. In 1961, short-term bank loans for the financing of imports and exports were liberalised and in 1968 non-financial Danish firms were granted permission to take out so-called financial loans abroad within certain maturity and size limits. However, most other private capital account transactions to and from Denmark still required permission from the Nationalbank during the Bretton Woods period. Furthermore, the access to financial loans abroad was tightened in 1973. The ceiling on financial loans was gradually increased during the 1970s and early 1980s and removed altogether in 1983.

In the 1960s and 1970s the Nationalbank also made use of various forms of credit rationing as monetary policy instruments. In the years 1965-1971 loan offers from the mortgage banks were subject to a quota system imposed by the monetary authorities after negotiations with the mortgage-credit organisations. During this period the Nationalbank also made use of deposits agreements as means of indirect regulating of lending from commercial/savings banks. In 1969, the Nationalbank issued guidelines for the amount of lending commitments extended by commercial/savings banks, and in 1970 a direct ceiling on lending commitments from individual commercial/savings banks was imposed. During the 1970s the Mortgage Credit Act was amended several times where the terms of the mortgage-credit loans were tightened in an attempt to limit the lending activities of the mortgage banks. Furthermore, in 1975 Danmarks Nationalbank and the Mortgage Credit Board entered into an agreement on a ceiling of the mortgage banks' total loan offers. In 1979 the lending activity of insurance companies and pension funds also became subject to regulation.

The quantitative elements in monetary-policy implementation were substantially reduced in the early 1980s. The ceilings on domestic lending from commercial/savings banks were dismantled in 1980 and the ceiling on the mortgage banks' loan offers was gradually lifted during the late 1970s and early 1980s. Furthermore, the regulation of the lending activity of insurance companies and pension funds was abolished in 1982.

As shown in Figure 7b there were two cases of clearly significant negative shocks to the credit mix in the period 1950-1980. The first occurred in 1965 when loan offers from the mortgage banks became subject to a quota system and when lending from commercial/savings banks became subject to indirect regulation via deposit agreements. The

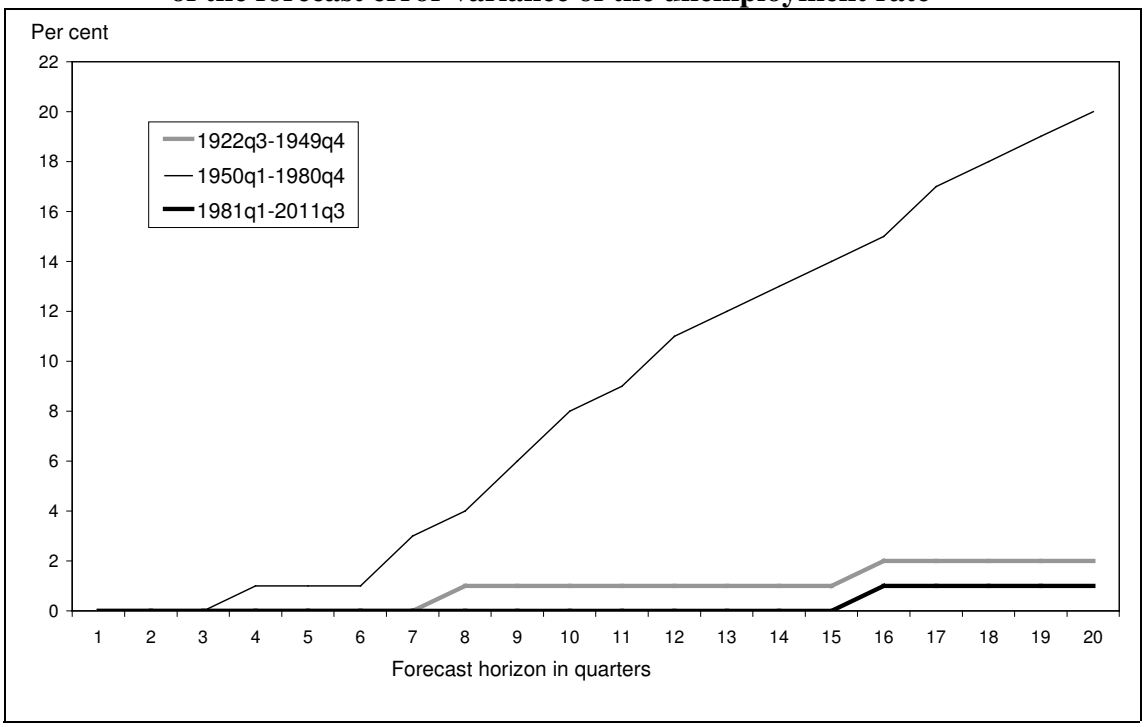
second occurred in 1969, when the Nationalbank issued guidelines for the amount of lending commitments extended by commercial/savings banks. The use of credit rationing and exchange controls as economic-policy instruments in the sub-sample period 1950-1980 might explain the significant increase in the unemployment rate and the decline in the industrial production index following a negative credit-supply shock in Figure 5 and 6c. However, as shown in Figure 6b the effect is not visible when we use real GDP as an indicator of economic activity.

A few remarks should be given to some of the other significant credit-supply shock Figure 7a-7c. The large negative credit-supply shock in 1947 in Figure 7a reflects the sale of special central-government bonds to the commercial banks in order to absorb some of the excess liquidity created during World War II by the German occupation forces' large expenditures in Denmark financed via German accounts at Danmarks Nationalbank, cf. Hoffmeyer and Olsen (1968). The positive credit-supply shock in 1980 in Figure 7b might reflect that the ceilings on domestic lending from commercial/savings banks were dismantled in 1980 as mentioned above. One can also note a positive credit-supply shock in 1991 in Figure 7c. This might reflect the switch to the new Basel I capital-adequacy rules in 1991. This meant that from then on the capital adequacy of Danish commercial/savings banks was to be measured against their risk-weighted assets rather than their total debt and guarantee commitments. The new rules entailed considerable easing of the statutory capital requirement for Danish commercial banks and savings banks, cf. Abildgren *et al*. (2010). Finally, the large positive credit-supply shock in 2000 in Figure 7c reflects the abolition as of 1 January 2000 of the Danish stamp duty on loan agreements, which were not filed with the Title Register. As a consequence, several commercial banks transferred loans to residents from foreign units (primarily based in Dublin) to banks or subsidiaries in Denmark, cf. Danmarks Nationalbank (2000).

In a VAR model the h-step forecast error for each variable can be expressed as a linear function of the structural shocks in the forecast period, cf. e.g. Krätzig and Lütkepohl (eds.) (2004). The forecast error variance can be decomposed to show the percentage contribution to the h-step forecast variance from each type of shocks in the model.

Figure 8 shows the percentage share that exogenous credit-supply shocks explain of the forecast error variance of the unemployment rate for various forecast horizons estimated for the three sub-samples mentioned above. In the sample periods 1922-1949 and 1981-2011 credit-supply shocks explained only a negligible share of the variance in the unemployment rate, whereas a non-trivial contribution from credit-supply shocks can be found for the period 1950-1980.

Figure 8: The percentage share that structural shocks to the credit mix explain of the forecast error variance of the unemployment rate



8. Finalising remarks and scope for further research

Summing up, this paper has examined the real effects of credit-supply shocks using a series of structural vector autoregressive (VAR) models estimated on the basis on a new quarterly data set for Denmark spanning the past 90 years or so.

We found no evidence of real effects from supply-shocks to credit from commercial/savings banks in the periods 1922-1949 and 1981-2011 even though these periods contained several cases of severe banking crises. We attribute this finding to the large market for mortgage-credit loans in Denmark raised through bond-financed mortgage banks combined with comprehensive government interventions to safeguard financial stability during times of crises.

There might, however, be indications of real effects from credit-supply shocks in the period 1950-1980 where credit rationing and exchange controls served as important economic-policy instruments.

Overall these results indicate that both the financial-system structure as well as the extent of government intervention during banking crises play a key role to the significance of real effects of credit-supply shocks. These findings must be kept in mind when modelling the role of financial intermediaries in macroeconomic models.

Naturally, these findings do not imply that there are no negative real effects of banking crises. But the results suggest that the transmission mechanism of banking crises in Denmark

have not primarily been through a significant contraction in the supply of credit from commercial/savings banks, which have affected the rest of the economy via lower investment and consumption by credit-constrained firms and households. The negative effects of banking crises seem rather mainly to have been transmitted to the real economy via other channels. This could for instance be through changes in the saving behaviour of households and firms due to weakened confidence in the banking sector and greater uncertainty about the future economic outlook, cf. also Abildgren *et al.* (2011). This issue, however, it left for future research.

Several other issues could also be the topic for future research, e.g. the possible asymmetric reactions or threshold effects related to positive and negative credit-supply shocks, cf. Calza and Sousa (2006). A related but more data demanding topic could be an exploration of cointegrating relations such as credit demand and credit supply equations estimated for the three subperiods 1922-1949, 1950-1980 and 1981-2011 in order to throw further light on the extent of credit shocks in different monetary and regulatory regimes.

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Appendix A: Technical specification of the structural VAR model

A VAR model is a system of linear equations where each of the endogenous variables is explained as a linear function of its own lagged values and the lagged values of all the other variables in the system. An unrestricted reduced-form linear VAR model can, in general terms, be written as:

$$[1] \qquad Y_t = CD_t + A_1 Y_{t-1} + ... + A_p Y_{t-p} + E_t$$

where Y_t is a vector of K endogenous variables and A_i (i=1,...,p) are time-invariant coefficient matrices. E_t is a vector of serially uncorrelated error terms with zero means and a time-independent variance-covariance matrix V. Finally, D_t is a matrix which contains a constant and a linear time trend, whereas C is the related time-invariant matrix of coefficients.

Since the right-hand side of [1] only contains predetermined variables, simultaneity is not an issue. Furthermore, since all the equations have the same explanatory variables, the coefficients can be estimated consistently and asymptotically efficiently by use of OLS directly to each equation in the VAR.[5] The variance-covariance matrix V of the reduced form error terms can then be estimated from the residuals.

Once the A_i coefficients are estimated, the marginal effect on the system at time t, t+1, t+2, ... of a shock to one of the endogenous variables at time t can be traced out from [1]. Such effects are usually termed "impulse responses" since they measure the marginal response of Y_t at time t, t+1, t+2, ... to a unit change at time t in one of the reduced form error terms in E_t. However, if the variance-covariance matrix V is not diagonal, a unit change at time t in only one of the reduced form error terms in E_t is implausible. The reduced form error terms therefore have no structural interpretation.

The underlying structural VAR model corresponding to the reduced form VAR model in [1] can be written as:

$$[2] \qquad BY_t = BCD_t + BA_1 Y_{t-1} + ... + BA_p Y_{t-p} + U_t$$

where:

$$[3] \qquad U_t = BE_t$$

[5] If the error terms furthermore follow a normal distribution the maximum likelihood estimates of the coefficients (conditional on the initia values) can also be found by the use of OLS directly to each equation in the VAR.

and where B is a time-invariant coefficient matrix specifying the contemporaneous interactions between the endogenous variables. U_t is a Kx1 vector of structural (or "orthogonal") shocks that are contemporaneously uncorrelated and thus have a diagonal variance-covariance matrix. There are K structural shocks in the system - one type of shocks to each of the endogenous variables. As indicated by [3] the reduced form error terms can be seen as a weighted average of the structural shocks that occur to each endogenous variable in isolation.

In this paper we rely on a Cholesky decomposition of V to identify the structural shocks. Since V is assumed to be symmetrical and positive definite, it can be uniquely decomposed as $V = LL^T$, where ^{T} denotes transponation and L is a KxK lower triangular matrix with zeros above the diagonal and the standard deviations along its principal diagonal. If we chose B so $L = B^{-1}$ the reduced form error terms in E_t can be written as $E_t = LU_t$. If U^j denotes a Kx1 vector with one in row j and zeros elsewhere, the impulse-responses to a one standard error structural shock to the endogenous variable no. j can then be traced out from LU^j and the estimated A_i coefficients in [1]. These impulse responses are typically denoted "orthogonalised impulse responses".

Since L is lower triangular, the Choleski decomposition imposes a contemporaneously recursive chain of causality on the system, i.e. the structural VAR model is recursive conditional on the lagged variables. A structural shock to the first endogenous variable at time t will have an instantaneous effect on all the other endogenous variables in the system. A structural shock to the second endogenous variable at time t will not have any effect at time t on the first endogenous variable but only on the other endogenous variable, *etc*. The effect of a structural shock to one of the endogenous variables in the system thus depends on the ordering of the endogenous variables in Y_t. This complicates the economic interpretation of the orthogonalised impulse-responses based on a Cholesky decomposition of V. However, a reasonable ordering might be based on economic arguments and the aim of the analysis. Furthermore, by estimating models with different ordering of the endogenous variables the robustness of the ordering can be assessed.

Deriving analytical expressions for the confidence intervals for impulse responses in large VAR models is rather complicated. Furthermore, the use of asymptotic theory relying on the normal distribution might not be appropriate in finite samples. It is therefore common to construct confidence intervals for impulse responses estimated in large VAR models using bootstrap methods. The 95 per cent confidence intervals around the estimated orthogonalised impulse responses shown in this paper are therefore bootstrapped confidence intervals. The method implies that 1,000 artificial data sets are generated utilising the original data set combined with 1,000 random drawings from the residuals of the estimated model (while

making sure that the residual correlation structure is taking into account). 1,000 VAR models are then estimated - one for each generated data set - and for each of these 1,000 estimated models impulse responses are calculated. The lower and upper limits of the 95 per cent confidence interval are then found as the 2.5th and 97.5th percentile of the distribution of these 1,000 impulse responses.

A final issue to consider is whether all the variables in the VAR need to be (trend) stationary or whether non-stationary variables can be included. Sims *et al*. (1990) notes that the parameters describing the systems dynamics and hence impulse responses are still estimated consistently in a VAR in levels even in the case where some or all of the variables are non-stationary. Furthermore, many test statistics still have the same asymptotic distribution as in the stationary case, cf. also Toda and Yamamoto (1995). A VAR in levels allows implicitly for potential cointegration among the variables and it might be argued that trending variables or deterministic trends could approximate unit roots with drift. A VAR in differences can be an alternative to a VAR in levels when non-stationary variables might be included, and a VAR in differences can serve as a useful robustness check to a level VAR. However, differencing throws away information and a VAR in differences is misspecified if some of the variables in levels are in fact stationary or cointegrated.