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The Exchange Rate. A Shock-Absorber or Source of Shocks? A Study of Four Open Economies

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Abstract[*]

The paper provides SVAR estimates for four open economies, those of the UK, Canada, Sweden and Denmark, making explicit a monetary policy reaction function and taking account of exchange rate targeting practices. The object of the analysis is to examine the idea that an independent money and exchange rate allow for effective shock-absorption. A polar extreme would be that exchange markets breed their own, and destabilizing, shocks. The paper's findings vary from one economy to another: monetary union appears easy to recommend for Sweden and Denmark, much less so for Canada and the UK.

Keywords: Optimal Currency Area, Structural Vector Autoregression, UK, Canada, Denmark, Sweden, EMU.

JEL: C32, E42, F31, F33

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1. Introduction

A key assumption of Optimal Currency Area (OCA) theory is that the possession of an independent currency and an exchange rate provides the country concerned with a potential means to stabilise against idiosyncratic shocks. The assessment of whether that country should relinquish its monetary independence and join a currency union with one or more partners then proceeds as a cost benefit analysis (Krugman, 1990). Since there are benefits from having a common currency the analysis turns on whether those benefits would outweigh the costs of foregoing the potential stabilisation effects of monetary independence. A different situation clearly arises if the foreign exchange market fails to offer any stabilisation benefit and, still more, if that market happens to provide an important independent source of shocks.

Given recent events in South East Asia it might come as no surprise to find that foreign exchange markets, so far from providing a stabilisation function, actually contribute towards destabilisation. In a recent comment on the position of the UK vis-à-vis the EMU, Buiter (1999a) has indeed suggested that a principal benefit of EMU membership for the UK might well be to escape from the destabilising effects of the sterling foreign exchange market: “I view exchange rate flexibility as a source of shocks and instability as well as (or even rather than) a mechanism for responding effectively to fundamental shocks originating elsewhere “ (ibid., p. 16).

An article IV consultation document of the International Monetary Fund (1999) has also drawn attention to the fact that output fluctuations in the UK have in recent decades been relatively large; and that “important roles for the interest rate and the exchange rate” in generating those fluctuations can be identified. These are important points, which potentially indicate a key weakness in the OCA approach.

The paper proceeds to examine the issue raised by Buiter empirically, using an SVAR approach. In order to provide perspective the scope of the analysis is deliberately not restricted to the UK, however. Rather, we have chosen to examine the position of four countries which, like the UK, have large neighbours with whom they trade a great deal, and with whom monetary union is an important policy option. The four economies concerned are those of: the UK, Canada, Sweden and Denmark.

The UK is presently exercising its ‘opt-out’ from the European Monetary Union, and the policy debate there concerns the issue of whether and in what circumstances, the UK should relinquish its opt-out. It is generally recognized that a positive decision is unlikely to come at all soon. Denmark, too, has an ‘opt-out’ from the European Monetary Union and awaits a referendum to reverse its exercise of this provision. This referendum will take place relatively soon. Sweden has no formal opt-out from the European Monetary Union but so far has chosen not to pass the qualifying criteria laid down in the Treaty of Maastricht. It is generally believed that a positive decision to qualify may be taken relatively soon. Canada has long exercised monetary independence from the United States and indeed does not presently have an option of ‘joining’ the United States as a full partner in a monetary union. But Canada could decide to adhere, say via a Currency Board arrangement, to the United States dollar. There has been a flurry of recent discussion of this type of option (see, e.g. Buiter (1999b), Courchene and Harris (1999), Laidler and Poschmann (1998)). As illustrated below (Table 1), of these four countries the UK is the largest in relation to its ‘neighbour’ (i.e., both Germany and the Euro-Area). Canada and Sweden are of similar size relative to their neighbour (Sweden’s neighbour being Germany), and Denmark is the smallest. When the relative size of Denmark and Sweden is measured against the Euro-Area, both countries are considerably smaller than Canada.

Using an SVAR approach to examine the topic in question seems the most obvious way to proceed. The methodology directly concerns itself with the stochastic behaviour of economies, which is the central issue here. Moreover, as detailed below, there are some antecedent studies with which our results can be compared. There is also a small but growing literature on SVAR estimation of open economies which provides some useful pointers for the current study.

Table 1: Country comparison: size and openness

	Size relative to neighbour*	Export share in GDP	Import share in GDP	Share of exports to neighbour*	Share of imports from neighbour*
Canada	0.09	40.7	39.0	0.83	0.67
Denmark	0.07 / 0.02	36.0	32.0	0.22 / 0.44	0.22 / 0.51
Sweden	0.10 / 0.03	43.8	36.8	0.11 / 0.38	0.19 / 0.49
UK	0.66 / 0.20	28.7	29.2	0.11 / 0.46	0.12 / 0.44

Sources: OECD Main Economic Indicators, IMF Direction of Trade Statistics, Own Calculations. *) Neighbour is US for Canada, Germany/Eurozone for the other countries. Relative size is measured on the basis of PPP-adjusted GDP. All data for 1997.

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2. Existing Studies

Existing studies which use SVAR techniques to focus on the question addressed here include those by Canzoneri et al. (1996), Funke (2000) and Thomas (1997). The IMF (1999) provides a provocative companion study. Whilst we address below in detail the issue of the type of SVAR we favour in this study a brief review of the existing studies is useful as a means of highlighting some common – and some different – features; and also with a view to establishing the 'conventional wisdom' in the field.

The study by Canzoneri et al. (1996) offers 2 and 3-variable SVARs as a vehicle for studying the stabilising role of the exchange rate in a number of European countries. The study embraces six countries – Austria, the Netherlands, France, Italy, Spain and the UK with quarterly data running from 1970 to 1985. The 2-variable VARs incorporate a nominal exchange rate and a relative output variable. The 'anchor' country, against which the exchange rate is defined and relative output measured is, initially, Germany and then in subsequent exercises, various definitions of the 'Core' (starting with a small core of Germany, Austria and the Netherlands, progressively adding first France and then Spain). To assist in identifying shocks with theory concepts the 2-variable VARs are supplemented by relative government expenditure or relative monetary velocity variables. The key restrictions which permit structural interpretations to be made of the estimates are similar to those suggested in Clarida and Gali (1994). The 3-variable systems allow identification of three shocks – a supply shock, a non-monetary demand shock and a nominal shock: the latter two are assumed to have no long run effect on output and the nominal shock not to influence the real exchange rate. In selecting the 'preferred' system the authors make substantial use, in the usual way, of over-identifying restrictions suggested by the relevant (Mundell-Fleming) theory. The key test to which the estimates are subjected is whether the shocks identified via the variance decompositions as most important for output are also those most important for exchange rate fluctuations. With the principal exception of Italy, the answer to this question turns out to be (an only mildly qualified) 'No'. At the one- to two-year horizon which seems most policy-relevant, the predominant finding is that the shocks explaining most of the output variation are supply shocks whereas those that explain the movement in the exchange rate are nominal shocks. A representative result is that, with respect to Germany, and on a horizon of two years, between 81 and 92 per cent of the variance of output is explained by supply shocks; whilst (excluding the case of Italy), the variation in exchange rates at a 2-year horizon is due as to only 16-20 per cent to supply shocks. The nominal shock is much more important in explaining exchange rate variations – between 59 and 69 per cent (again, excluding Italy). The authors cautiously conclude that "The exchange rate seems to be acting more like an asset price than the 'shock absorber' described by the literature on optimal currency areas". This is not to say, however, that exchange rate shocks spill over to affect output. The nominal shock accounts for only 2-6 per cent of output variation. It is just that the exchange rate is moving in response to shocks other than those that drive output responses.

Funke's (2000) study reaches a not-dissimilar conclusion. Funke analyses the UK in relation to Euroland, using quarterly data for the period 1980:1 to 1997:4 (for data reasons Luxembourg is excluded from the aggregation). The SVARs are defined for relative output, the real ECU/£ exchange rate and relative inflation. Using an identification scheme based on Clarida and Gali (1994) Funke distinguishes between supply shocks, real non-monetary demand shocks and nominal shocks. The variance decompositions show that relative output is driven overwhelmingly by supply shocks (at all horizons) whereas the real exchange rate is driven only as to some 18 per cent by those shocks and predominantly by demand shocks (over 64 per cent). The author concludes that "the real ECU exchange rate has not played the shock absorber role that the optimal currency literature suggests" (ibid., p. 18).

Thomas's study of Sweden (Thomas, 1997) also employs the Clarida-Gali identification scheme. Data on relative GDP, relative prices and the real exchange rate over the period 1979:1 to 1995:4 are used in a first system, with relative government consumption replacing relative prices in a second system. Long run zero restrictions are identified in the response of output to demand and to nominal shocks and in the response of the exchange rate to nominal shocks, in the same way as in the other studies. The exchange rate in this study is defined as a real effective (trade-weighted) exchange rate against Sweden's 15 principal trading partners, with relative output, prices and government consumption being defined against weighted aggregates of the same fifteen countries. Forecast error variance decompositions then show that at horizons of up to 8 quarters supply shocks account for most of relative output, with demand and nominal shocks also supplying a non-negligible proportion of the variance. By contrast, the real exchange rate responds little to supply shocks but predominantly to demand shocks, with nominal shocks also playing a non-negligible role. So far as these results go, then, the outcome in the Swedish case is somewhat more nuanced than those established by Canzoneri et al. and by Funke for their cases. Nevertheless, Thomas concludes that Sweden would have little to lose from joining EMU provided that the demand shocks can be interpreted as "controllable policy shocks". A tentative demonstration that these shocks are indeed associated with fiscal policy completes the paper.

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The IMF study of the UK (IMF, 1999) reports estimates of a VAR model for the UK which yields provocative results in pointing to an important role for exchange rates and interest rates in accounting for the rather exceptional fluctuations in output in that country, especially in the 1980s. Whilst the system estimated is inspired by the modified Dornbusch-Mundell-Flemming model underlying the previous studies considered here, the analysis does not yield a complete structural account and does not provide material for an analysis of variance decompositions.

This brief account of some studies which have attempted explicitly to evaluate the shock-absorbing role of the exchange rate allows for some concluding general comments.

All of the structural VAR analyses reviewed have followed the example of Clarida and Gali (1994) in specifying the variables under consideration in relative terms. The logic for doing so is obvious: the exchange rate itself is a 'relative' variable and a drastic parsimony in the specification is permitted. Nevertheless, a strong restriction – that the transmission mechanism of shocks in the economies compared is similar – is also implied. Whilst views differ on how large these differences are, we are quite impressed by their apparent size in the case of a monetary policy transmission (e.g. Ehrmann 2000). Moreover, the "relative" formulation identifies only asymmetric shocks and thus yields no information on the comparative frequency of symmetric and asymmetric shocks. These observations will provide us with a point of departure subsequently for suggesting an alternative SVAR specification. Second, it is worth recalling a well-known, but easily overlooked, caution in the interpretation of stabilisation effects. If variable x (a policy instrument or stabilising variable) *perfectly* stabilises shocks which could impinge on variable y, then the *ex post* data will reveal variations in x and none in y: but it would be a mistake to conclude that x was ineffective as a shock absorber! Third, in each of the SVAR studies reviewed here, the countries concerned are ones in which some degree of exchange rate targeting has been practised for part, at least, of the sample period. Unless special account is taken of this the results may well be uninformative. The central banks' role in exchange rate management for the countries studied in this paper is illustrated in table 2, where we present an intervention index for all four countries. The index follows Weymark (1995) and takes the value 0 for a freely floating exchange rate, the value 1 for a fixed exchange rate, and intermediate values for intermediate cases where the central bank intervenes to reduce some exchange market pressure. A value above 1 indicates that the central bank's reaction "overcompensates" the exchange market pressure. As can be seen the index confirms a high degree of exchange rate intervention for Denmark and Sweden, with Canada and the UK as intermediate cases.

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Table 2: Intervention index, measured against the US$ for Canada, the DM/ECU otherwise (for details see appendix)

Canada	Denmark	Sweden	UK
0.50	1.04 / 0.74	0.92 / 0.77	0.36 / 0.38

Finally, whilst the SVAR studies reviewed above concentrated on the role of the exchange rate, it is worth recalling that OCA theory privileges the exchange rate as a key to an independent monetary policy. Thus a full evaluation of this issue should attempt to make explicit a role for monetary policy. In the succeeding sections we set up an alternative SVAR identification and proceed to use it to describe the economies of the UK, Canada, Sweden and Denmark. In doing so we endeavour to take account of the concluding comments above.

3. Econometric Methodology

We now turn to an alternative SVAR specification. Following the seminal contribution by Sims (1980), SVARs have become a frequently used tool in gauging the effects of monetary policy, and as such are useful in our framework, too. Most of the applications have been concerned with the US economy, and have been fairly successful in identifying monetary policy effects. After encountering various empirical puzzles like the price or liquidity puzzle initially, later contributions have managed to avoid such counterintuitive results.

The countries we focus on in this paper are open economies, however, and in this area the SVAR methodology has not yet reached a consensus as how to overcome all the puzzles that have been encountered (e.g., the exchange rate puzzle, first found by Grilli and Roubini (1995) which shows an exchange rate depreciation following a contractionary monetary policy shock in the open economy). Several recent contributions devise strategies to find an appropriate representation of SVAR models for open economies. Whereas Bagliano *et al.* (1999) develop a new indicator for monetary policy surprises, Kim and Roubini (1997), Faust and Rogers (1999), Cushman and Zha (1997) and Smets (1997) employ various identification schemes to properly account for the specificities of open economies. These contributions seem to converge in that the main issue for modelling an open economy is to identify the role of the exchange rate in the creation and propagation of disturbances.

For our purposes, we set up a VAR model consisting of $x_t = [\Delta y_t \quad r_t^* \quad r_t \quad \Delta p_t \quad \Delta e_t]'$, where, all variables except the interest rates being in logs Δy_t denotes output growth, r_t^* the foreign short-term nominal interest rate (i.e. of the currency block the countries might consider joining), r_t the home short-term nominal interest rate, Δp_t inflation and Δe_t the rate of appreciation of

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the nominal exchange rate of the home currency against the currency block (i.e., against the US$ or the ECU). The model is formulated as

$$A_0 x_t = A(L)x_{t-1} + \varepsilon_t , \qquad (1)$$

with $\varepsilon_t \sim iidN(0, \Sigma_\varepsilon)$.

This model implies that the set of variables is subject to a vector of structural shocks, ε_t. These are comprised of $\varepsilon_t = [\varepsilon_t^s \quad \varepsilon_t^d \quad \varepsilon_t^{m^*} \quad \varepsilon_t^m \quad \varepsilon_t^e]'$, where ε_t^s indicates a supply shock, ε_t^d a demand shock, $\varepsilon_t^{m^*}$ and ε_t^m foreign and home monetary policy shocks and ε_t^e the exchange rate shock. We refer to the last three as "nominal" shocks.

Equation (1) cannot be estimated – for estimation, the model has to be converted into its reduced form

$$x_t = A_0^{-1} A(L)x_{t-1} + A_0^{-1}\varepsilon_t , \qquad (2)$$

which is not identified; to reconstruct (1) from the estimated parameters of (2), 25 identification assumptions need to be imposed (equal to the number of parameters in the matrix A_0). Fifteen of these arise from the standard assumption that the structural errors have unit variance and are uncorrelated, i.e. $\Sigma_\varepsilon = I$. The other ten restrictions are derived as follows:

Firstly, we identify the supply shock as the only one in the system which has a permanent effect on output.[1] This follows Blanchard and Quah (1989) and is equivalent to four restrictions, namely four zero-restrictions on the long-term effects of the demand and nominal shocks on output. The matrix where the restrictions are imposed is derived from the moving average representation of the system

$$x_t = B(L)\varepsilon_t \qquad (3)$$

The long-run effect of ε_t on x_t is thus given by $B(1)$, a $5x5$-matrix. The restrictions are imposed by setting the second to the fifth element in the first row to zero.

Secondly, we assume that none of the nominal shocks has immediate effects on output (or, in other words, that only the demand and supply shocks can influence output instantaneously); this imposes three more restrictions, namely zeros on the third to fifth element in the first row of $B(0)$. We furthermore assume that the foreign interest rate does not react

[1] This means that we rule out the possibility of exchange rate shocks having a long run effect on output. Here we adopt Macdonald's (1999) interpretation of the evidence as being that real exchange rates are (albeit slowly) mean-reverting. "Beachhead" and "pricing to market" models (Krugman (1989) and Dixit (1989)) help explain the slow pace of mean-reversion rather than underpinning hysterisis.

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contemporaneously to a monetary policy shock in the home country, nor to an exchange rate shock. This assumption is justified by the special cases we are looking at in this paper: the large country's central bank is probably not very much concerned about the small country changing interest rates, and will therefore not react to a monetary policy shock there. The same should hold for the large country's exchange rate against the small country. This way, two more identification restrictions have been found, again by imposing zeros on $B(0)$. The last restriction follows Smets (1997) and will be explained in more detail in the next paragraph.

With both an interest rate and the exchange rate in the VAR, it is no longer straightforward to distinguish whether shocks to these variables are monetary policy shocks or whether they "are due to the monetary authorities' response to shocks to the exchange rate that could arise from speculative capital movements, changes in the risk premium or foreign interest rate changes" (Smets 1997: 598). We have accounted for the latter by explicitly modelling the foreign interest rate, but still have to find a credible identification scheme to disentangle monetary policy from exchange rate shocks. All the countries under study here have experienced periods of exchange rate targeting, as indicated in Box 1. Hence identifying this appears crucial. To do so, we follow the approach advised by Smets. He assumes that, once the effects of supply and demand shocks have been accounted for, the residuals in the reduced form consist of two parts, namely a contribution from the monetary policy shock and one from the exchange rate shock:

$$u_t^r = \alpha_1 \varepsilon_t^m + \alpha_2 \varepsilon_t^e \tag{4}$$

$$u_t^e = \beta_1 \varepsilon_t^m + \beta_2 \varepsilon_t^e \tag{5}$$

Equation (4) shows that the interest rate is determined by the autonomous monetary policy setting, ε_t^m, as well as in response to exchange market shocks, ε_t^e. Equivalently, the exchange rate depends on domestic monetary policy shocks as well as exchange market disturbances.

The model (4) to (5) can be solved for the structural monetary policy shock, ε_t^m:

$$\varepsilon_t^m = \frac{\beta_2}{\alpha_1\beta_2 - \alpha_2\beta_1} u_t^r + \frac{\alpha_2}{\alpha_1\beta_2 - \alpha_2\beta_1} u_t^e \tag{6}$$

Equation (6) denotes how the central bank sets its monetary policy, given the current interest rate and the exchange rate. Normalising the sum of the weights on the two residuals to one, we arrive at

$$\varepsilon_t^m = (1-\omega) u_t^r + \omega\, u_t^e, \tag{7}$$

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where $\omega = -\frac{\alpha_2}{\beta_2 - \alpha_2}$. α_2 as defined in (4) is expected to be negative, since an appreciation of the exchange rate should lead to a fall in the interest rate. β_2, on the other hand, should be positive, as is obvious from (5). It follows that $\omega \in [0,1]$. By estimating the parameter ω, the identification problem can be solved, because then it is possible to identify the structural monetary policy and exchange rate shocks from the reduced form residuals. Transforming (7) into a regression model yields

$$u_t^r = -\frac{\omega}{1-\omega} u_t^e + \frac{1}{1-\omega} \varepsilon_t^m, \tag{8}$$

a non-linear regression where the regressor and the disturbance are obviously correlated. Hansen (1982) has suggested a GMM estimator for these cases, which contains the 2SLS-IV-estimator as a special case. The choice of instruments and the exact specification of the estimation follows Smets (1997). With the estimate for ω, it is then possible to calculate the response functions and variance decompositions for the various shocks to the system.

4. Empirical Results

4.1. Model set-up

We estimate the model in turn for each of the four countries. The variables used are industrial production, a domestic and a foreign short-term interest rate (US rates as foreign rates for Canada, German rates as a proxy for Eurozone rates for Denmark, Sweden and the United Kingdom),[2] consumer prices (RPIX for the United Kingdom), and the nominal exchange rate against the US dollar for Canada, against the ECU for Denmark, Sweden and the United Kingdom. As has become common practice in SVAR models of monetary policy, we also allow for commodity price inflation shocks. However, we assume that they arise exogenously for the small countries under study here, so that we do not have to impose any more identification restrictions.[3] All data but the interest rates are in logarithms; they are all monthly and seasonally adjusted. Unit root tests are supplied in the appendix. Each model allows for a linear trend and is estimated with 6 lags.[4] For Canada, the sample period is post-Bretton Woods 1974:1 to 1998:12; for all the other countries it starts shortly after the creation of the ERM,

[2] Canada: 3 month treasury bill rate; Denmark: call money rate; Germany: 3 month money market rate; Sweden: 3 month treasury discount notes rate; UK: overnight interbank rate; US: federal funds rate.

[3] Commodity prices are denoted in U.S. dollars; the results are fairly robust to the exclusion of commodity price inflation.

[4] The linear trend removes non-stationarities in some variables; e.g. inflation is often downwards trending for our sample. The lag length was commonly chosen for all countries, ensuring that the residuals are well specified.

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spanning 1980:1 to 1998:12. The models are stable over time, as is shown in figures 7 to 10 in the appendix.

In Denmark and Sweden, we correct the VARs for outliers during the 1992/93 exchange rate crisis; in both countries, interest rates reached unprecedented levels of around 20% *p.a.*, roughly doubling the otherwise prevailing levels of interest rates. These extraordinary occasions might be interesting *per se*, but including them in the VAR would distort the estimates.

It might be questioned whether the set-up of our models allows for the identification of foreign monetary policy shocks. The foreign central bank, when setting its monetary policy, is mainly guided by the developments in its own country, much less so by those in the small neighbour (which is precisely the effect feeding into the identification restrictions for the impulse responses). Identification of foreign monetary policy shocks would then mean, however, that the foreign economy has to be modelled explicitly, too; foreign inflation and output growth are natural candidates that should be considered. Tests on the reduced form surprisingly show that such an explicit modelling is not needed after all: the exclusion restrictions on the foreign variables cannot be rejected for nearly any of the cases, as shown in table 7 in the appendix. Consequently, we continue the analysis with the smaller models.

4.2. Estimates for ω

As a first step, we estimate ω, the weight the central banks attach to the exchange rate. The results for various sample periods are reported in table 3 (with t-statistics in brackets). The value of 0.34 (with a standard deviation of .11) for Canada is fairly encouraging: the current exchange rate enters directly into the Bank of Canada's MCI (weighted by a factor of 1/3), which should be reflected in a significantly positive estimate for ω.[5] For Denmark, the weight is, not unexpectedly, higher. Splitting the sample to check for robustness before and after the ERM exchange rate crisis of 1992/93 yields a fairly stable weight. This is not the case for Sweden, though. Sweden abandoned its exchange rate target in 1992 after the exchange rate crisis and switched to an inflation targeting regime; this is reflected in the estimate of ω falling and furthermore becoming insignificant. Nonetheless, the overall estimate is surprisingly low, given that the Swedish Riksbank was targeting a trade-weighted exchange rate up to 1992:11 (see Box 1). For the UK, the estimates turn out to be in a similar range. During British ERM membership (1990:10- 1992:8), however, ω is around twice as big as before and after. For the post-ERM period, when the

[5] See also http://www.bank-banque-canada.ca/english/mci2.htm.

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monetary policy regime abandoned the exchange rate target in exchange for an inflation target, ω turns out to be insignificant.

Table 3: Estimates for ω in equation (8)

Canada		Denmark		Sweden		United Kingdom	
74:1-98:12	0.34 (3.20)	80:1-98:12	0.53 (1.98)	80:1-98:12	0.14 (2.71)	80:1-98:12	0.14 (3.90)
		80:1-92:12	0.53 (2.54)	80:1-92:11	0.16 (2.65)	80:1-90:9	0.13 (2.33)
		93:1-98:12	0.64 (4.05)	92:12-98:12	0.06 (0.69)	90:10-92:8	0.22 (2.73)
						92:9-98:12	0.10 (1.43)

Admittedly, the estimates of ω for all countries but Canada are somewhat lower than one would expect *a priori*, especially when compared with the estimates in Smets (1997), who finds 0.75 for France and 0.38 for Italy. It should be noted, however, that the models in this paper explicitly account for a foreign interest rate shock, which is not the case in Smets (1997). In his model, ω must be higher, since it includes also the effects of foreign monetary policy. As a matter of fact, Smets' smaller four-variable model for Denmark yields an estimate of $\omega = 0.85$, much larger than $\omega = 0.53$ as we find it here. In our approach, a central bank which follows the monetary policy strategy of the large neighbour closely (like, e.g., Denmark), can nonetheless exhibit a relatively low ω.

To interpret the credibility of our estimates for ω, we consider it more useful to investigate its behaviour over time, to check whether the estimates replicate changes in monetary policy regimes, rather than putting too much emphasis on the estimated level of ω. As shown in table 3, the estimates track the developments in monetary policy regimes (as detailed in Box 1) rather well. Additionally, we will perform robustness tests for the impulse response analyses, to ensure that the results do not depend critically on the estimates obtained for ω.

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Canada

Since June 1970, Canada has been operating a floating exchange rate regime, with the exchange rate subject to considerable swings. The Bank of Canada did at times, however, manage the exchange rate, like in February 1986, where downward pressure on the Canadian dollar was fought off.

Monetary policy was initially set around a target for a narrow monetary aggregate, M1. After abandoning M1 as target in 1982, no other explicit target was announced until the introduction of an inflation target in February 1991. In order to achieve this target, the Bank of Canada formulates a monetary conditions index (MCI) as operational target, considering both short-term interest rates and the exchange rate.

Denmark

Denmark participated in the EMS from its start in March 1979. Initially subject to several devaluations, the exchange rate stabilised from September 1982. The depreciation against the DM slowed down considerably, and the depreciation against the ECU turned into a steady appreciation. The ERM exchange rate crisis of 1992/93, however, hit also the Danish krona: up to December 1992, several interest rate increases and foreign exchange interventions were necessary to defend the exchange rate. In August 1993, the ERM fluctuation bands were widened from ±2.25% to ±15%. At present, Denmark participates in ERM2. Although the fluctuation bands are ±2.25%, the Nationalbank is at present targeting a fixed exchange rate and regards the bands as a safety net.

Sweden

The Swedish Riksbank started targeting a trade-weighted exchange rate in 1977. On several occasions, this exchange rate was subject to considerable market pressure. Whereas in many cases, this pressure could be relieved by central bank actions, sometimes it led to sizeable devaluations like in September 1981 and in October 1982. In 1989, all exchange controls were abolished, and in May 1991 the krona was pegged to the ECU, with a fluctuation band of ±1.5%. In November 1992, however, the krona was forced out of the currency peg despite attempts to support it during the ERM crisis. Two months later, an inflation target was announced. It is presently set to a CPI-inflation rate of 1-3%.

United Kingdom

From 1980, the Bank of England had emphasised monetary aggregates (initially £m3) as intermediate targets, but already in the mid-1980s a broader set of indicators was referred to. The exchange rate gained importance in the range of indicators after 1986; for approximately one year, although never officially declared, monetary policy shadowed the DM: Sterling moved within a narrow band just below 3 DM. In October 1990, when Sterling entered the ERM, the exchange rate became the official monetary policy target. Sterling's ERM membership was suspended in September 1992, after which an inflation targeting regime was introduced. In 1997 the Bank of England acquired full instrument independence and was asked to pursue an inflation target (for RPIX) of 2½ per cent.

Box 1: Monetary policy and exchange rate policy history during the sample periods
Sources: OECD Country Surveys, Central Banks, Artis and Lewis (1991)

4.3. Impulse Responses and Variance Decomposition

The results of the impulse response analysis are reported in figures 1 to 4 in the appendix, and those for the forecast error variance decomposition are provided in table 5. The calculations are performed with the estimate of ω obtained from the full sample period, i.e. .35 for Canada, .5 for Denmark, .15 for Sweden and the United Kingdom (for a sensitivity analysis see figures 5 and 6 in the appendix). Note that the differenced variables in the VARs are now represented in levels, i.e. output, prices and exchange rates rather than their growth rates.

The impulse responses are shown with bootstrapped 10% confidence bounds. We have not managed to completely eliminate puzzling responses, yet the vast majority of the impulse responses are as expected. In response to a supply shock, we would expect to see output increasing, home interest rates decreasing, prices falling and the exchange rate depreciating. The demand shock, whilst also leading to an increase in output should, on the other hand, be accompanied by an increase in domestic interest rates, a rise in prices, and an appreciation of the exchange rate. Responses to a foreign monetary policy shock can go either way, depending on the domestic central bank's reaction. After a contractionary monetary policy shock, modelled by increasing domestic interest rates, reasonable responses would imply that output falls, as well as prices, and that the exchange rate appreciates. The foreign interest rate should not react, or at least not very strongly, if our belief holds true that the large country is not very much concerned about monetary policy shocks in the smaller country. Finally, an exchange rate depreciation should ideally lead to rising output, home interest rates and prices.

The most notable case where the impulse responses appear puzzling occurs for the British price response to nominal shocks. For all three nominal shocks, a price puzzle is evident. The puzzle is very robust to changes in the model set-up. It seems to be mainly originating in the early 1980's, since we can eliminate most of it by shortening the sample period to start in 1983:7; additionally, however, we have to convert the commodity prices into Sterling. On the other hand, the models are very successful in avoiding the exchange rate puzzle.

4.3.1. Supply and Demand Shocks

To interpret the nature of supply and demand shocks, it is interesting to have a look at the response of both the foreign and domestic interest rates. Shocks that are predominantly asymmetric require opposed responses of foreign and domestic monetary policy (if the foreign central bank responds at all); symmetric shocks, on the other hand, should be accompanied by symmetric

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monetary policy (and thus interest rate) responses. For Canada, Denmark and Sweden we find significant responses of foreign interest rates that are furthermore symmetric to the domestic response, which suggests that both the domestic and the foreign economy are hit mainly by symmetric shocks, necessitating a parallel response of the respective interest rates. The case is different for the UK, however. Here, the foreign interest rate does not react significantly to either the supply or the demand shock. The directions of response, furthermore, are opposed to those of the domestic interest rate, consistent with a conclusion that demand and supply shocks for the UK vs. the Eurozone are predominantly asymmetric.

These results confirm our motivation to deviate from the earlier SVAR studies on the topic. Measuring all variables relative to the neighbour reduces the analysis to one of asymmetric shocks, making it is impossible to gauge whether such shocks are important. For the case of the UK, such a model seems justified, whereas for the other countries the role of the exchange rate as a shock absorber would be implicitly overestimated. If asymmetric shocks occur only infrequently, then the loss of the exchange rate as stabiliser is less severe than it is for a country which needs a stabilising tool more often, because it is hit by asymmetric shocks frequently.

4.3.2. Nominal Shocks

The three nominal shocks have very different effects on output in the four countries studied. Denmark and Sweden's output responses to these shocks are quantitatively negligible (each shock explains less than one percent of the variance in output at nearly all time horizons), and furthermore insignificant. This would suggest that the two countries can be relatively indifferent as to whether they pursue their own, independent, monetary policy, or join a monetary union. Matters are different for Canada and the UK, on the other hand. Here, nominal shocks can affect output to some extent (their sum explains more than five percent of output variations for some horizons), and the responses are estimated to be significant. With nominal shocks as a tool to influence output, an independent monetary policy looks more attractive (with the prerequisite that monetary policy can effectively influence inflation, which is the case for all countries in our study). Note also that the persistence of the interest rate responses is important: the more persistent, the larger the effects of nominal shocks on the real economy. Not surprisingly so; if a small country finds it difficult to sustain an interest rate differential towards the large neighbour (which implies low persistence of the interest rate response in the SVARs), then the effects of such an interest rate deviation are obviously bound to be smaller.

For Canada, the monetary policy shock explains most of the variation in output among the three nominal shocks, which hints at a fairly influential role of the domestic monetary policy. For the UK, on the other hand, the nominal shock which explains most of the variance of output is the foreign rather than the domestic monetary policy shock. This is a rather surprising finding – why should the Bank of England not try to shelter the economy from the output effects of an overseas monetary policy innovation?

Such an interpretation of the impulse responses might go too far, however. A closer inspection of the UK's domestic monetary policy shock reveals that in this case, our identification scheme (which assumed that the country is small relative to its neighbour) is hitting a borderline case. As indicated in table 1, the UK is, in comparison to its neighbour, by far the largest of the four economies, and as such it might be that the large neighbour, contrary to our identification assumptions, does sometimes react to a domestic monetary policy shock. As a matter of fact, the response of German interest rates to a British monetary policy shock turns out to be significant at some horizons. It is therefore possible that the identification scheme has problems separating the two monetary policy shocks. Regardless of this identification issue, however, it holds in any case that the UK has the potential to influence both inflation and output through monetary policy – and it is up to the Bank of England to choose how to distribute this potential between following a European monetary policy and pursuing an idiosyncratic policy.

The foreign monetary policy shocks show a surprising response of domestic interest rates for the cases of Denmark and Sweden. *A priori*, we would expect that these small countries would follow interest rate surprises by the large neighbour – for the Danish case in particular, since the Danish Nationalbank for most of the sample period followed the Bundesbank's policy closely. Figures 2 and 3, however, show domestic interest rate reactions which counteract the foreign interest rate move. A possible explanation for this counterintuitive result is that these shocks are actually reactions of the foreign central bank to exchange rate movements. Our identification restrictions rule out that the foreign central bank reacts to exchange rate shocks. This is reasonable if it is shocks to the currency of the small country. The foreign central bank might, however, be concerned if these shocks hit its own currency instead, and respond accordingly. Such cases appear as foreign monetary policy shocks in our figures. Note that none of our results is affected by such a re-interpretation.

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4.3.3. The Role of the Exchange Rate

To judge the role of the exchange rate as shock-absorber, it is necessary to analyse its behaviour subsequent to supply and demand shocks. For none of the countries are the responses of the exchange rate significant. Furthermore, the reactions are relatively weak: the variance decompositions show that only a small proportion of the exchange rate variability can be attributed to demand and supply shocks. This is logical for Canada, Sweden and Denmark anyway – if the shocks are symmetric in nature, then no exchange rate adjustment is needed to restore equilibrium. For the UK, on the other hand, where we have classified the shocks to be predominantly idiosyncratic, our results could support a minor role for the exchange rate as shock-absorber.

The major source of variability in exchange rates according to our results are nominal shocks: a depreciation following a foreign monetary policy shock, an appreciation caused by a domestic monetary policy shock, and shocks arising in the foreign exchange market itself. For Canada, the exchange rate reacts strongly to monetary policy shocks. It seems to play an important role in the transmission of monetary policy. The shocks created by the exchange rate, on the other hand, are of less importance for inflation and the real economy. Denmark suffers comparatively more from exchange rate shocks: a depreciation leads to considerable inflationary pressure, whereas it does not noticeably affect the real economy. Sweden's exchange market looks more like a source of shocks than a shock absorber or shock transmitter: around ninety percent and more of the variance of the exchange rate is explained by the exchange rate shock itself at all horizons! Nonetheless, an exchange rate shock does not transmit major disturbances to the price level or the real economy. In the UK, the exchange rate plays, similarly to Canada, an important role in the transmission mechanism of monetary policy. It reacts strongly to a monetary policy shock, but is also a prominent source of disturbances itself: but once again, as in the case of Sweden, the effects of an exchange rate shock on the real economy appear to be of minor magnitude.

5. Conclusions

The aim of this paper has been to cast light on the central issue in OCA theory – the stabilizing properties of an independent monetary policy and exchange rate. We have examined this question in the context provided by four open economies – the UK, Sweden, Denmark and Canada – each of which faces an important policy option of monetary union (or a similar arrangement) with a big neighbour.

We chose to tackle this question with an SVAR specification which draws on the SVAR literature on monetary policy in an open economy. The specification can be viewed as allowing for an identification of the symmetry of shocks between the smaller country and its large neighbour: this is indicated by the similarity in the shock-response of the large country's monetary policy to that of the smaller one.

Then, the specification also allows us to examine directly what shocks the exchange rate predominantly responds to. In similar fashion, we can also discover what shocks predominantly drive output and monetary policy. Finally, we can discuss whether, in fact, monetary policy has significant effects on real output and prices and at what horizons.

Table 4 sums up our results through five criteria that are relevant for the evaluation of the monetary union options. All criteria are formulated such that a positive answer favours monetary union. Symmetry in shocks constitutes a positive indicator for monetary union as it suggests that stabilisation is little called for. Evidence that monetary policy has little effect on output is also a positive indicator, as is evidence that the exchange rate is largely driven by shocks arising in the exchange market itself. The latter suggests that the exchange market so far from absorbing shocks, is creating its own. If the exchange rate tends to behave as a source of shocks, then monetary union is even more favourable if these shocks affect output and/or prices strongly.

Table 4: Criteria to evaluate monetary union option

Criterion	Canada	Denmark	Sweden	UK
Supply and demand shocks predominantly symmetric	+	+	+	-
Monetary policy has little effect on output	-	+	+	-
Exchange rate not very responsive to supply and demand shocks	+	+	+	+
Exchange rate largely driven by shocks in the exchange market	-	(+)	+	+
Exchange rate shocks distort output and/or prices	NA (+)	+	-	+

What do these results suggest about the monetary union option for these countries? On this basis, in the case of *Sweden*, where shocks appear predominantly symmetric, the exchange rate appears to "dance to its own tune" and monetary policy has little effect on output, there seems little doubt that monetary union would involve no loss. For *Denmark*, a similar verdict is available. The reasoning is slightly different. Shocks appear mainly symmetric,

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again, but the exchange rate is quite strongly driven by monetary policy innovations, and monetary policy itself responds to demand and supply shocks. However, the evidence is that monetary policy in Denmark has no effect on output. Once again, then, monetary union would occasion no loss. In the case of *Canada*, whilst shocks are mainly symmetric, monetary policy has real effects, and the exchange rate is driven by relative monetary policy effects and even to some extent by demand and supply shocks themselves (since the exchange rate is not mainly a source of shocks, the question whether exchange market shocks distort output and/or prices is not relevant). A stabilizing role is feasible for monetary policy and the exchange rate. Monetary union, or in this case "dollarization" could involve loss. For the UK, there are inconsistent indications: shocks are asymmetric and monetary policy is (weakly) effective for output. On the other hand, a large component of variation in the exchange rate is due to exchange market disturbances themselves: demand and supply shocks are negligibly involved. Monetary policy itself is strongly influenced by innovations in foreign monetary policy. The outcome for the monetary union option is not clear cut.

The results obtained in any SVAR exercise are only as good as the identification scheme that is employed to 'make sense' of the residuals. The restrictions involved here are, largely, conventional in that they have been adopted in earlier studies of monetary policy effectiveness; and the over-identifying restrictions suggested by theoretical priors are all largely satisfied in our results. Nevertheless it cannot be ruled out that comparatively 'minor' changes in specification could produce a different picture. The appendix carries a sensitivity analysis in respect of variations in our assumptions about the 'degree' of exchange rate targeting; in this case, although a number of detailed results are changed none of our main conclusions is perceptibly affected. This evidence of the robustness of our conclusions is of course welcome, though at this stage we still prefer to view the current paper as a preliminary exploration of the important issues under review.

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Appendix

Figure 1: Impulse Response Functions for Canada

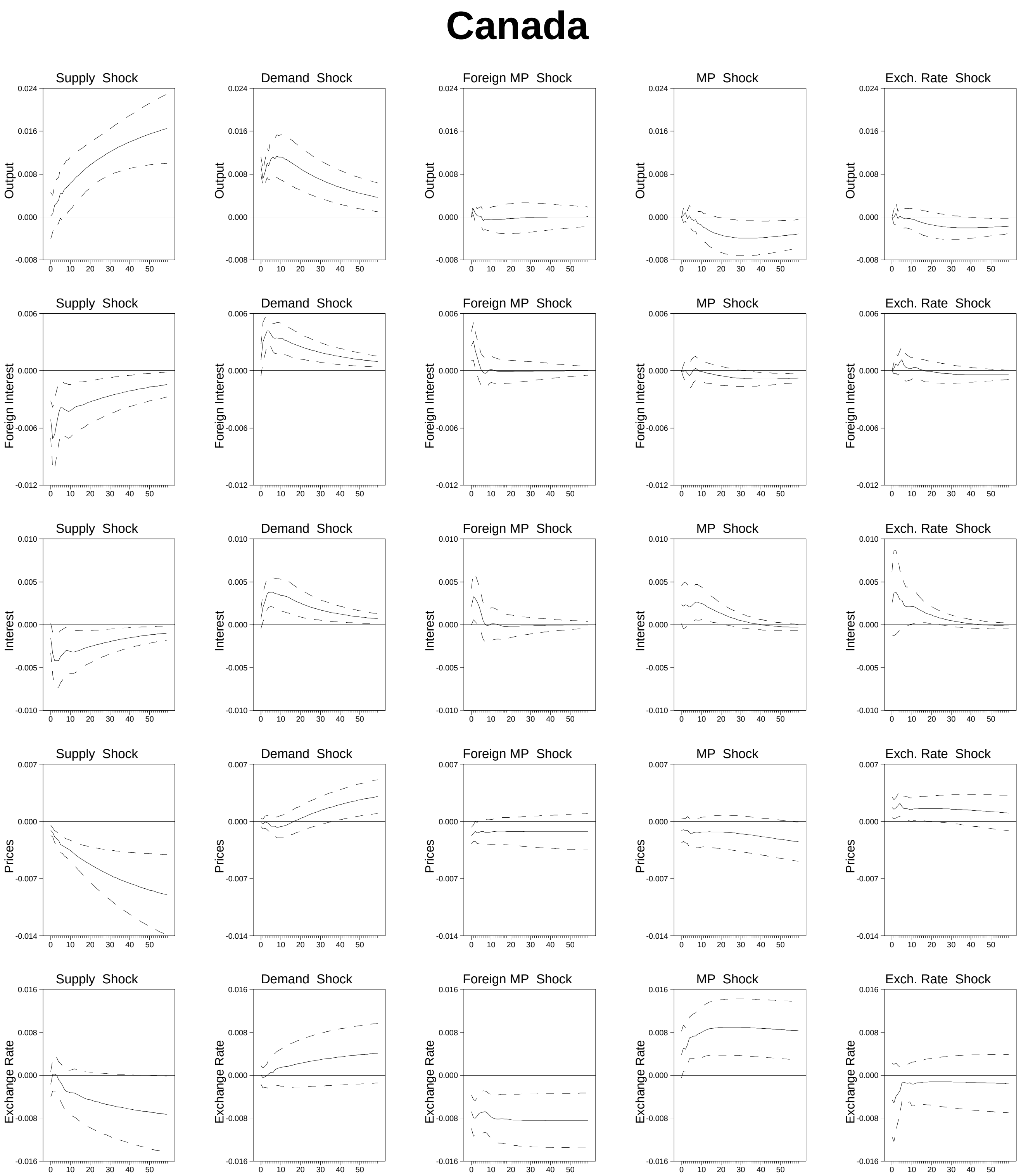

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Figure 2: Impulse Response Functions for Denmark

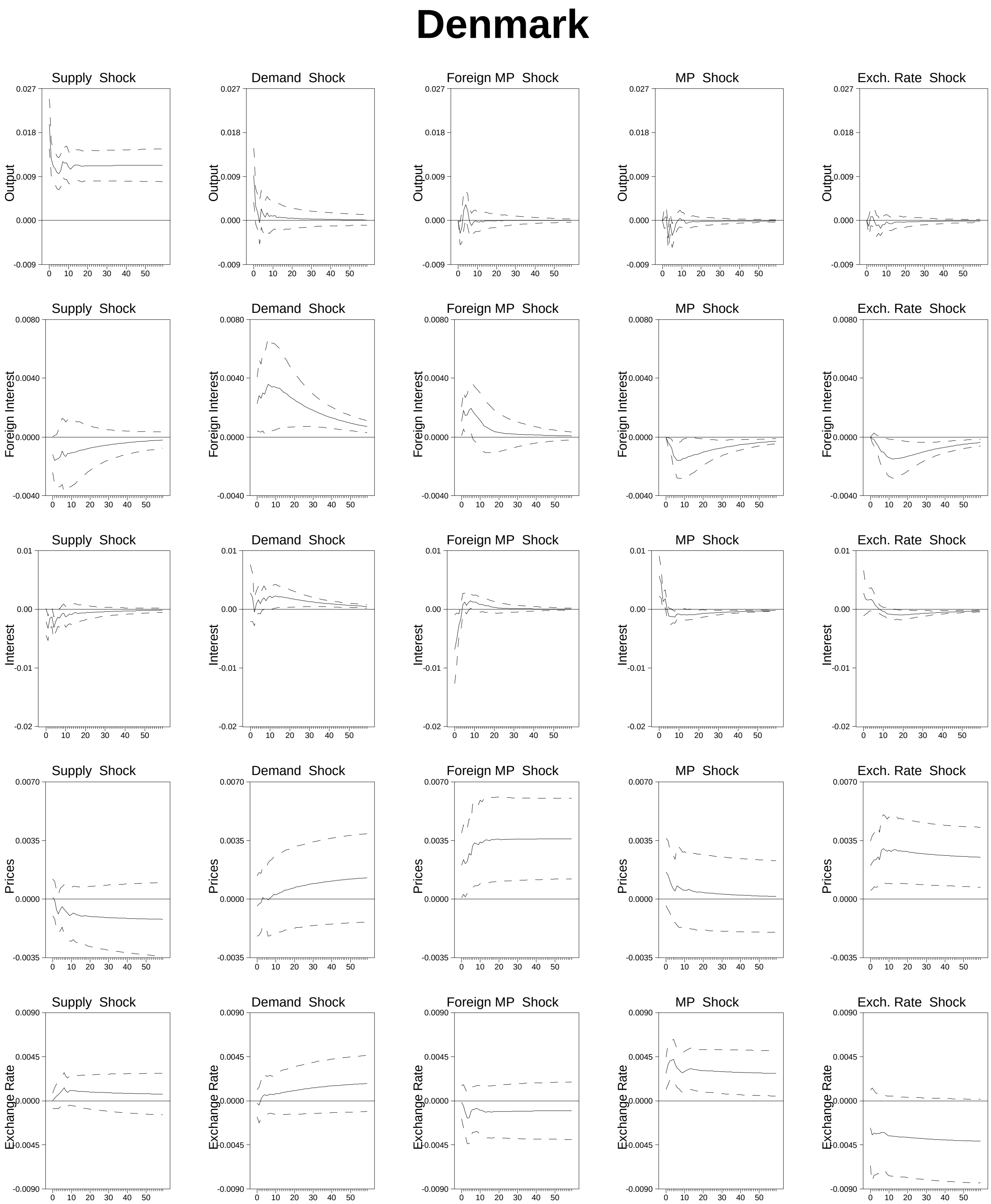

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Figure 3: Impulse Response Functions for Sweden

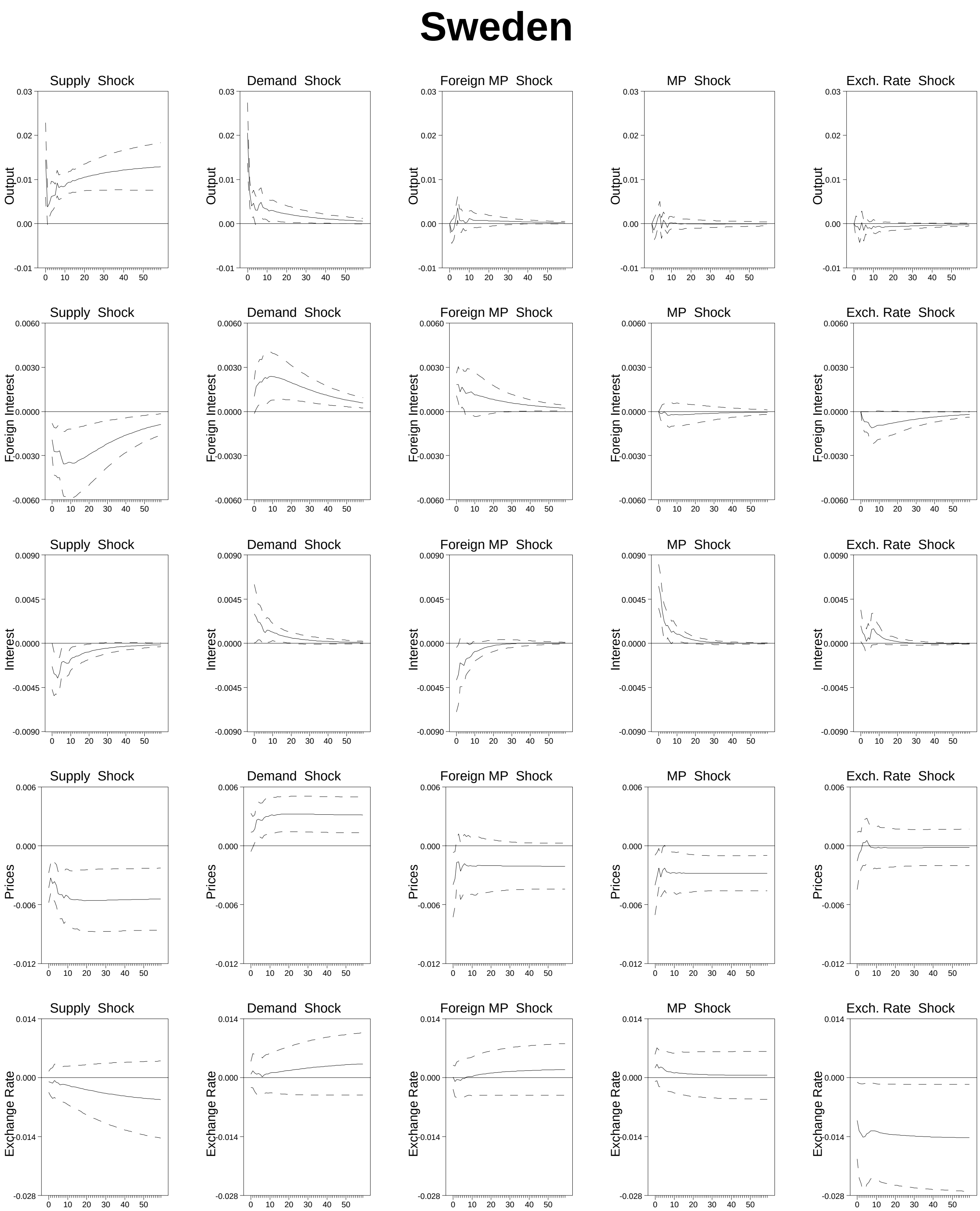

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Figure 4: Impulse Response Functions for the United Kingdom

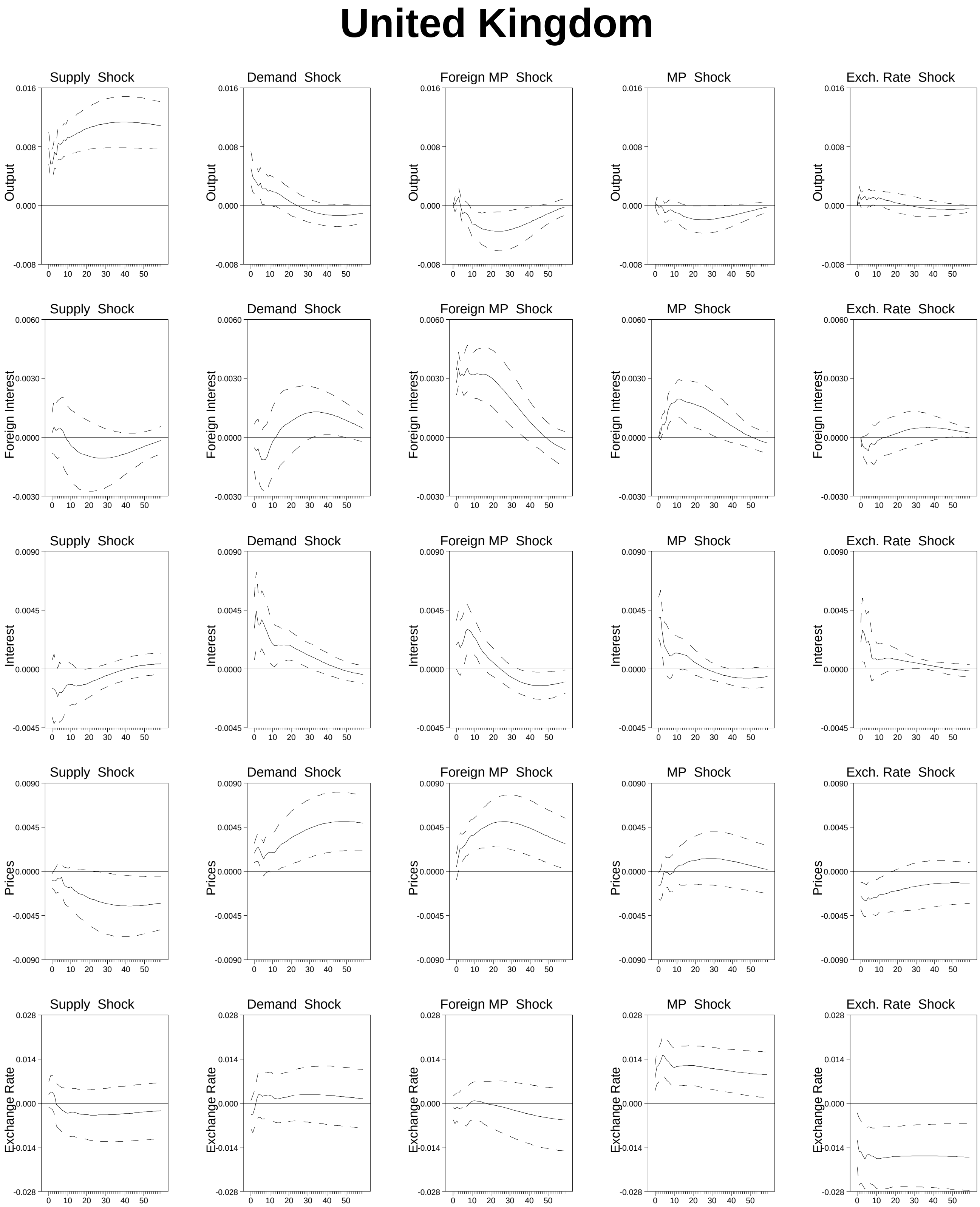

Table 5: Variance Decompositions

Canada Variance decomposition for output					
Step	Supply Shock	Demand Shock	Foreign Mon. Pol. Shock	Monetary Policy Shock	Exchange Rate Shock
1	0.05	99.95	0	0	0
12	15.54	83.38	0.28	0.72	0.08
24	32.17	63.88	0.15	3.27	0.53
36	46.58	47.54	0.09	4.79	0.99
48	57.68	35.96	0.06	5.12	1.18
60	66.02	27.93	0.05	4.83	1.17
Variance decomposition for US interest rates					
1	76.37	3.64	19.99	0	0
12	62.39	31.42	5.23	0.12	0.84
24	61.59	33.94	3.45	0.42	0.6
36	61.41	33.87	2.88	1.19	0.65
48	61.11	33.43	2.61	2.03	0.82
60	60.8	33.03	2.46	2.72	1
Variance decomposition for interest rates					
1	12.69	2.86	23.66	28.44	32.36
12	30.14	27.86	8.2	14.52	19.28
24	32.7	31.65	5.44	14.05	16.15
36	34.86	32.73	4.83	12.89	14.69
48	36.14	33.06	4.59	12.25	13.96
60	36.83	33.11	4.46	12.01	13.59
Variance decomposition for CPI					
1	14.68	0.16	35.69	14.45	35.01
12	53.82	1.84	12.98	11.66	19.7
24	72.13	0.93	7.46	7.61	11.87
36	78.68	2.21	5.15	5.99	7.97
48	80.82	4.05	3.92	5.59	5.62
60	81.35	5.68	3.16	5.69	4.13
Variance decomposition for exchange rate					
1	3.49	0	54.26	17.34	24.91
12	4.07	0.69	47.55	40.39	7.3
24	8.03	1.76	43.04	43.61	3.55
36	11.23	2.8	40.62	42.9	2.45
48	13.9	3.76	39.03	41.32	1.99
60	16.2	4.62	37.85	39.57	1.77

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Denmark
Variance decomposition for output

Step	Supply Shock	Demand Shock	Foreign Mon. Pol. Shock	Monetary Policy Shock	Exchange Rate Shock
1	82	18	0	0	0
12	90.66	5.85	1.54	1.48	0.46
24	94.6	3.36	0.86	0.86	0.31
36	96.22	2.36	0.6	0.6	0.23
48	97.09	1.81	0.46	0.46	0.18
60	97.64	1.47	0.37	0.37	0.14
Variance decomposition for German interest rates					
1	18.77	66.16	15.07	0	0
12	9.9	61.1	14.06	9.51	5.42
24	8.27	62.78	8.9	10.13	9.92
36	7.86	63.05	7.58	10.23	11.27
48	7.72	63.14	7.11	10.27	11.76
60	7.66	63.18	6.92	10.29	11.96
Variance decomposition for interest rates					
1	4.66	8.01	46.99	32.59	7.75
12	15.48	14.89	35.81	25.51	8.31
24	13.49	25.97	29.02	22.32	9.19
36	12.77	29.58	26.37	21.25	10.04
48	12.48	31	25.32	20.82	10.38
60	12.36	31.61	24.87	20.64	10.52
Variance decomposition for CPI					
1	0.09	1.54	37.7	24.12	36.55
12	2.99	0.3	50.12	4.82	41.76
24	3.86	1.06	53.64	2.57	38.87
36	4.44	2.02	55.07	1.79	36.68
48	4.87	2.93	55.85	1.37	34.98
60	5.19	3.73	56.34	1.11	33.62
Variance decomposition for exchange rate					
1	0	0.37	0.15	50.77	48.7
12	3.05	1.25	4.42	47.33	43.94
24	3.17	2.42	4.51	42.05	47.86
36	2.94	3.72	4.36	38.75	50.23
48	2.69	4.95	4.2	36.28	51.88
60	2.49	6.02	4.06	34.37	53.07

Sweden
Variance decomposition for output

Step	Supply Shock	Demand Shock	Foreign Mon. Pol. Shock	Monetary Policy Shock	Exchange Rate Shock
1	33.03	66.97	0	0	0

12	55.29	41.79	1.51	0.77	0.65
24	73.33	24.71	1.01	0.41	0.54
36	82.19	16.41	0.72	0.26	0.41
48	87.1	11.86	0.54	0.18	0.32
60	90.09	9.1	0.42	0.14	0.25

Variance decomposition for German interest rates

1	45.83	12.87	41.3	0	0
12	57.64	26.1	11.69	0.21	4.35
24	60.04	26.95	8.61	0.23	4.17
36	60.72	27.2	7.8	0.22	4.06
48	60.98	27.3	7.49	0.22	4
60	61.09	27.35	7.37	0.21	3.98

Variance decomposition for interest rates

1	8.4	13.85	21.15	51.68	4.92
12	27.28	14.96	18.62	33.94	5.2
24	29.48	15.73	17.71	31.94	5.13
36	30.08	15.95	17.44	31.48	5.06
48	30.27	16.02	17.35	31.32	5.03
60	30.34	16.05	17.32	31.26	5.03

Variance decomposition for CPI

1	33.58	3.43	29.11	29.54	4.34
12	50.7	15.88	13.39	19.25	0.78
24	54.74	17.91	10.27	16.7	0.39
36	55.84	18.5	9.41	15.98	0.27
48	56.27	18.73	9.09	15.69	0.22
60	56.47	18.84	8.94	15.56	0.18

Variance decomposition for exchange rate

1	0.84	0.58	0.02	4.89	93.67
12	1.2	0.57	0.11	2.24	95.88
24	2.46	0.95	0.31	1.31	94.97
36	3.87	1.49	0.57	0.91	93.16
48	5.22	2.04	0.78	0.7	91.27
60	6.41	2.52	0.94	0.57	89.57

United Kingdom

Variance decomposition for output

Step	Supply Shock	Demand Shock	Foreign Mon. Pol. Shock	Monetary Policy Shock	Exchange Rate Shock
1	69.79	30.21	0	0	0
12	83.95	11.59	2.54	0.55	1.36
24	85.99	5.3	6.39	1.57	0.74
36	87.42	3.23	6.97	1.94	0.44
48	89.31	2.63	5.94	1.75	0.36
60	91.09	2.34	4.8	1.44	0.32

Variance decomposition for German interest rates					
1	0.62	3.38	96	0	0
12	0.96	4.72	78.95	14.17	1.19
24	3.31	4.06	73.65	18.28	0.71
36	5.62	7.36	67.64	18.28	1.1
48	6.79	10.28	63.77	17.57	1.58
60	6.96	11.35	62.65	17.22	1.81
Variance decomposition for interest rates					
1	6.37	27.79	9.99	43.78	12.06
12	9.39	37.63	23.23	17.87	11.88
24	11.51	39.53	21.62	16.14	11.2
36	11.62	40.43	21.46	15.32	11.17
48	11.03	38.51	24.27	15.55	10.64
60	10.79	36.77	26.45	15.87	10.12
Variance decomposition for RPIX					
1	7.27	26.76	1.79	16.43	47.75
12	7	17.06	40.99	2.08	32.85
24	11.95	20.49	47.63	2.29	17.64
36	14.94	26.09	45.18	2.55	11.24
48	16.96	31.43	40.83	2.28	8.49
60	18.28	35.76	36.79	1.89	7.29
Variance decomposition for exchange rate					
1	3.13	6.03	0.91	29.02	60.9
12	1.53	1.45	0.35	35.88	60.8
24	2.07	1.13	0.2	33.58	63.02
36	2.44	1.31	0.4	32.02	63.84
48	2.47	1.34	1.1	30.24	64.86
60	2.32	1.23	2.04	28.46	65.94

Sensitivity Analysis

Figures 5 and 6 present estimates of the monetary policy and exchange rate shocks for varying estimates of ω. Only the impulse responses to these two shocks depend on ω, whereas for all others the identification remains unchanged. The solid lines represent the results for $\omega = 0$ (i.e. a situation where the central bank does not take into account the exchange rate for its monetary policy at all), the dashed lines those for ω as estimated for the full sample and used in the body of the paper, and the short-long-dashed lines denote the results for ω twice as big as estimated for the full sample. In some cases, the results change considerably. For Sweden, ignoring the role of the exchange rate in the monetary policy setting would lead to an exchange rate puzzle. For Canada, a price puzzle would result. On the other hand, setting ω to zero for the United Kingdom and to one for Denmark would help to avoid the price puzzles. For the exchange rate shock, it is interesting to see that $\omega = 0$ leads to a basically non-existent interest rate response to exchange rate shocks for all horizons. Doubling ω for Canada produces implausible results where the interest rate

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reaction is so strong that the initial exchange rate depreciation is reversed into a highly persistent appreciation, a result which supports our estimate for ω.

In any case, the results of this paper do not depend crucially on the choice of ω. Firstly, it affects only two out of the five shocks, and secondly, the overall picture of which shock drives the exchange rate, whether monetary policy is effective and whether exchange rate shocks have a big effect on output is not changed.

Figure 5: Sensitivity of responses to a monetary policy shock

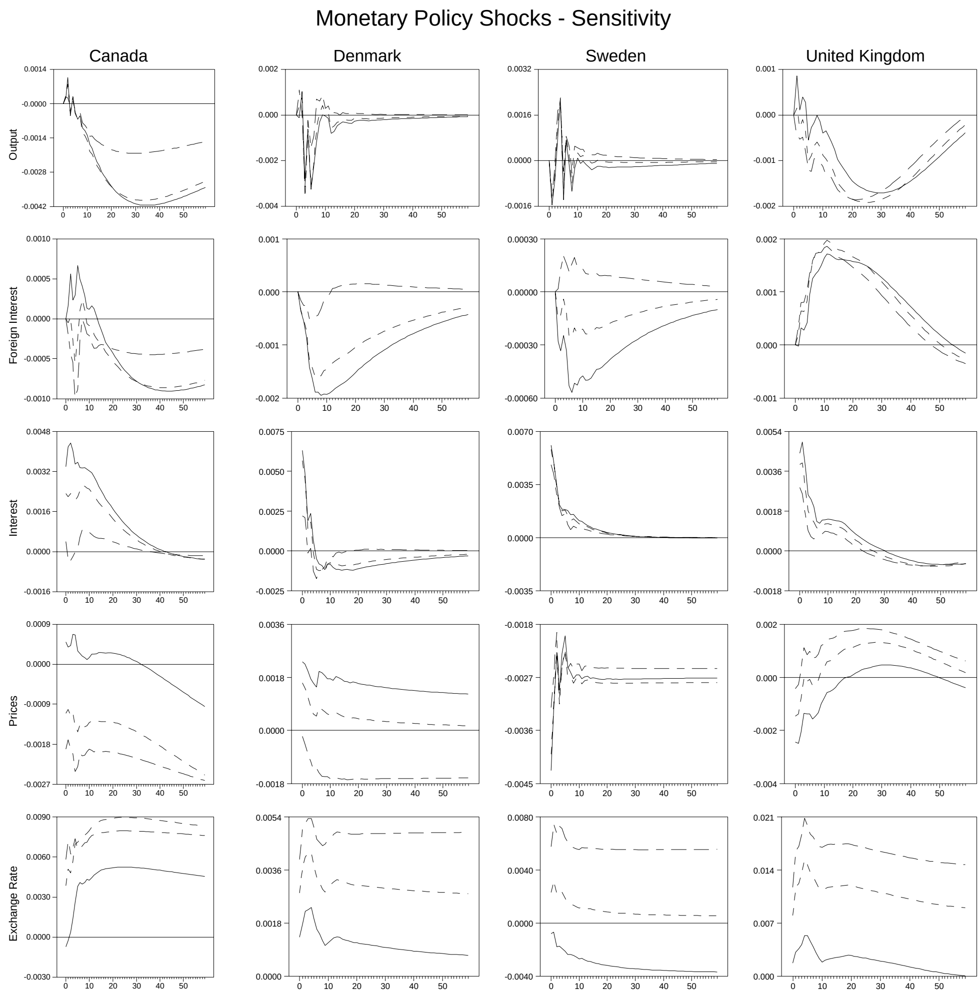

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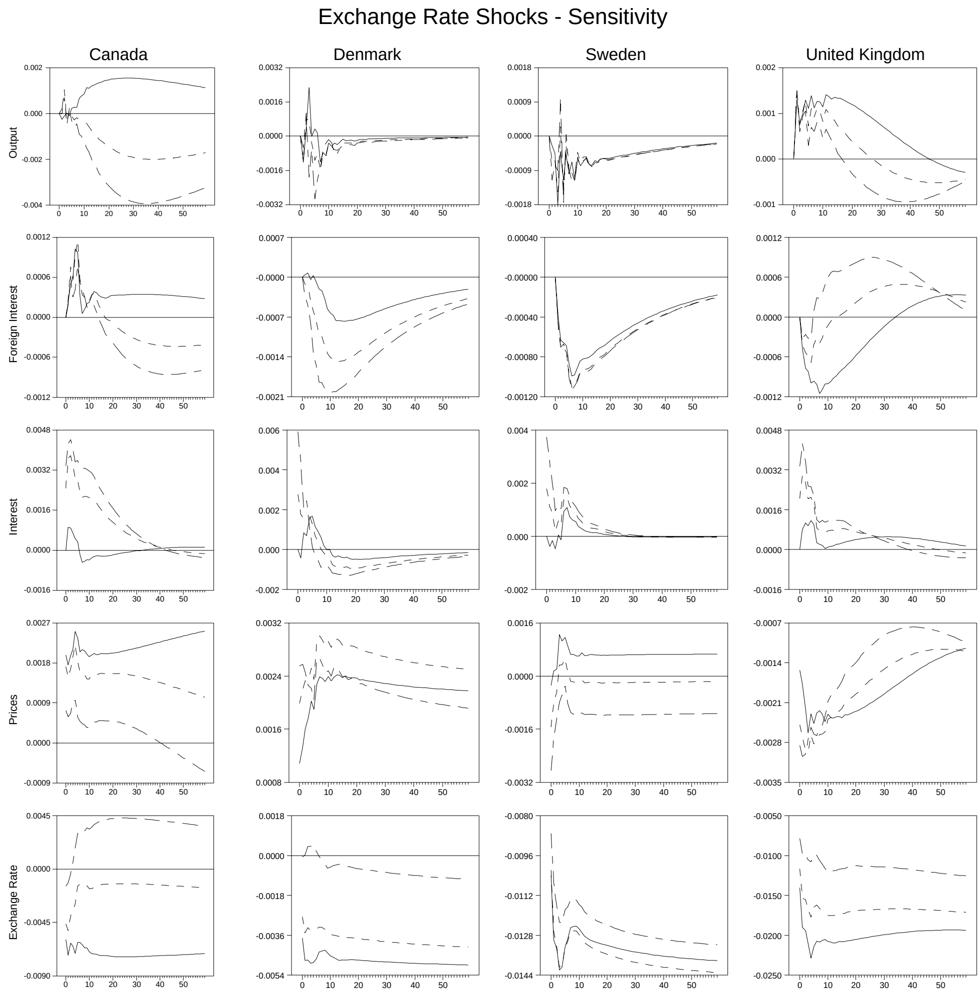
Figure 6: Sensitivity of responses to an exchange rate shock



Unit root tests

Univariate unit root tests like the augmented Dickey-Fuller test revealed possible nonstationarities for the interest rate series of the US, Germany and the UK. All the other variables turned out to be stationary (in their first differences as they enter the VARs). To judge the degree of integration of series, it is, however, advisable to perform unit root tests within the VAR system. Johansen's tests for the cointegration rank in our six-variable VARs favour a rank of six, indicating that all series can indeed be considered stationary when estimated in the VAR system (see table 6). For Sweden, the cointegration rank is estimated to be lower. Nonetheless, for comparability, we treat the Swedish variables as stationary. Another indicator that the assumption of stationary interest rates is admissible can be found in the impulse responses. They return to baseline quickly, with converging error bounds. This is generally not the case if the variables are integrated.

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Table 6: Results of Johansen's trace test for cointegration rank

	r = 0	r = 1	r = 2	R = 3	r = 4	r = 5
Critical values (90%)	89.37	64.74	43.84	26.70	13.31	2.71
Canada	235.12	130.19	78.03	36.27	13.96	4.08
Denmark	271.45	170.47	102.77	52.85	14.76	2.74
Sweden	286.64	175.04	108.60	50.08	8.90*	1.16*
UK	258.91	160.46	98.90	53.66	16.37	5.66

Calculation of the intervention index in table 2

The index follows Weymark (1995), with slight modifications. It is supposed to measure the extent to which central banks used foreign exchange reserves for interventions in the foreign exchange market in order to influence the exchange rate. According to Weymark, exchange market pressure can either lead to exchange rate changes or be absorbed by an appropriate central bank intervention. Exchange market pressure is thus defined as

$$EMP_t = \Delta e_t + \eta \Delta r_t, \qquad \text{(A1)}$$

where Δe_t denotes the change in the nominal exchange rate (with e_t measured as the logarithm of the exchange rate of the domestic versus the foreign currency), Δr_t the change in foreign exchange reserves[6] and $\eta = -\frac{\partial \Delta e_t}{\partial \Delta r_t}$ the elasticity which converts the reserve changes into equivalent exchange rate units.

Dividing (A1) by EMP_t yields

$$1 = \frac{\Delta e_t}{EMP_t} + \frac{\eta \Delta r_t}{EMP_t}, \qquad \text{(A2)}$$

the first term of which denotes the proportion of the exchange market pressure that is relieved by an exchange rate change, the second term of which indicates the proportion that is relieved by intervention activities of the central banks. The intervention index is then defined as

$$\tau_t = \frac{\eta \Delta r_t}{EMP_t} = \frac{\Delta r_t}{\left(1/\eta\right)\Delta e_t + \Delta r_t} \qquad \text{(A3)}$$

Whereas Δe_t and Δr_t are readily observable, η needs to be estimated from a structural model. We re-estimate Weymark (1995) here, and refer to the original for further details.

From equation (A2) the properties of the index can be easily derived: for the case of a freely floating exchange rate, the index takes the value 0 because all exchange market pressure is relieved by an according exchange rate change. A fixed exchange rate leads to a

[6] We deviate from Weymark's original definition here. We do not express the change in the foreign exchange reserves as a proportion of the inherited monetary base. Furthermore, we do not correct it with the money multiplier. The reserves are denominated in US$ for all countries.

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value of 1 for the index, because the first term in (A2) is zero. Intermediate cases lead to a value of $0 < \tau_t < 1$.

Table 2 reports the average of the index over the estimated sample, which spans 1974:1 to 1998:12 for Canada, 1980:1 to 1998:12 for Denmark and Sweden and (due to data availability) 1982:6 to 1998:11 for the UK.

Exclusion test for the extended models

In extended models, which include also foreign inflation ($\pi *$) and output growth ($\Delta y *$), we test whether the coefficients on $\pi *$ and $\Delta y *$ in the equation on foreign interest rates are zero (joint test). Additionally, we provide equivalent tests in models where only one foreign variable ($\pi *$ or $\Delta y *$) had been included.

Table 7: Tests for exclusion of foreign variables; significance levels in brackets;
joint test is $\chi^2(12)$, single tests are $\chi^2(6)$

	Canada	Denmark	Sweden	UK
Joint test	21.18 [0.05]	14.32 [0.28]	16.01 [0.19]	12.76 [0.39]
$\pi *$	6.23 [0.40]	12.09 [0.06]	14.19 [0.03]*	12.83 [0.05]
$\Delta y *$	19.17 [0.00]**	2.20 [0.90]	1.78 [0.94]	3.09 [0.80]

Stability tests

Figures 7 to 10 report breakpoint Chow-tests for the VARs of each country. Despite the fairly long sample, which covers various monetary policy and exchange rate regimes for some countries, the results support stability of our VARs. Merely for the Danish industrial production equation, there seem to be problems, which are not reflected in the system estimates, however.

Figure 7: 5% Breakpoint Chow tests for Canada

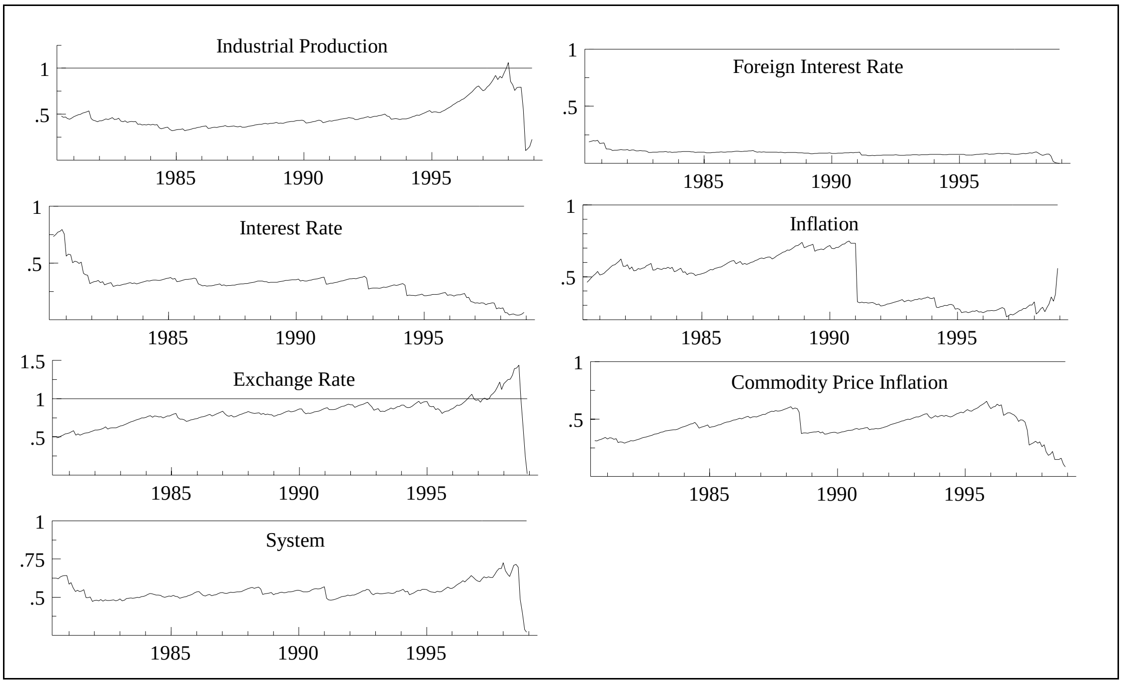

Figure 8: 5% Breakpoint Chow tests for Denmark

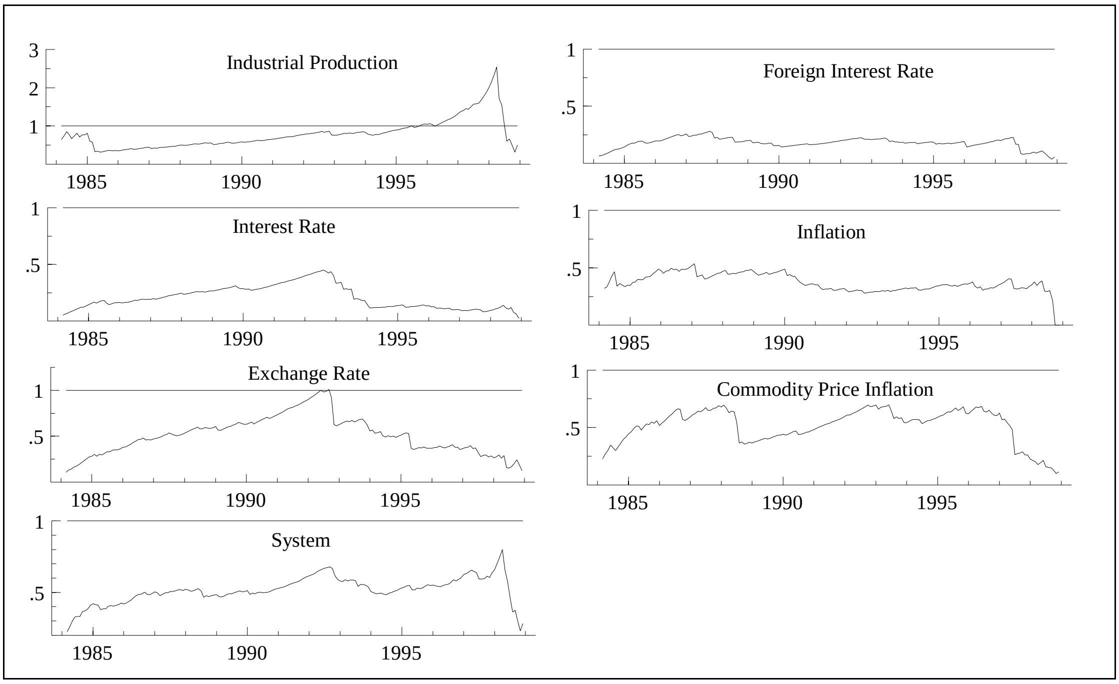

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Figure 9: 5% Breakpoint Chow tests for Sweden

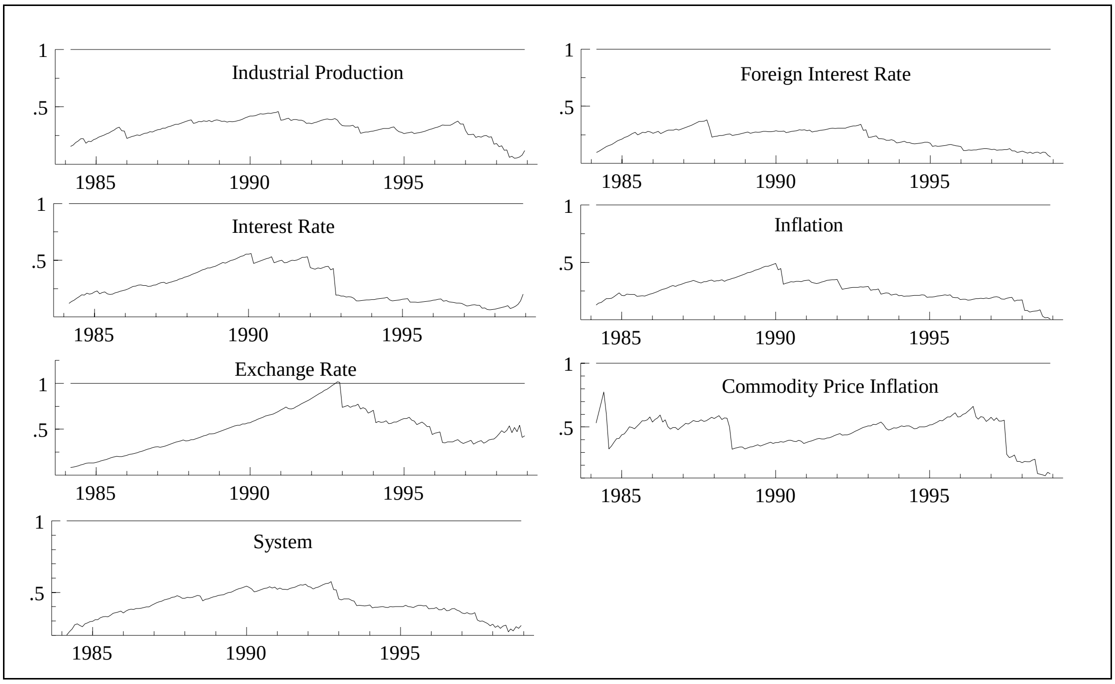

Figure 10: 5% Breakpoint Chow tests for the United Kingdom