MOSES: Model for Studying the Economy of Sweden.*

Gunnar Bårdsen[†], Ard den Reijer[‡], Patrik Jonasson[§] and Ragnar Nymoen[¶]

January 2012

Abstract

MOSES is an aggregate econometric model for Sweden, estimated on quarterly data, and intended for policy simulations and short-term forecasting. After a presentation of qualitative model properties, the econometric methodology is summarized. The model properties, within sample simulations, and forecast evaluations are presented. We also address methodology and practical issues relating to building and maintaining a macro model of this type. The detailed econometric equations are reported in an appendix.

"I think it should be generally agreed that a model that does not generate many properties of actual data cannot be claimed to have any 'policy implications'..."
Clive.W. J. Granger (1992, p. 4).

1 Introduction

MOSES is a small aggregate econometric model for Sweden. The model is actively used by the Swedish Riksbank, both for policy analysis and short-term forecasting.

This paper first gives a presentation of qualitative model properties, with the aid of graphics and references to macroeconomic theory. The theory behind some key aspects of the model are then discussed in more detail, before the econometric methodology used in the specification of the model is summarized. A presentation of the model properties follows in the form of simulations. Forecasts from the model for the period 2010(1)-2013(4) are presented together with outcomes for 2010(1)-2010(3). Finally, a forecast comparison with two other models in use by the Riksbank is conducted. The results of the econometric modelling are reported in detail in an Appendix.

2 Qualitative properties of MOSES

MOSES represents several of the most important functional relationships in the Swedish macro economy in a small, data- and theory-coherent model. This is done by econometric

*We are grateful to Ulf Söderström for very helpful and detailed comments on an earlier version. Gunnar Bårdsen and Ragnar Nymoen worked as consultants for the Riksbank on this project. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Executive Board of Sveriges Riksbank.

[†]NTNU Norwegian University of Science and Technology, Trondheim.
E-mail: Gunnar.Bardsen@svt.ntnu.no

[‡]Sveriges Riksbank, Monetary Policy Department, SE-103 37 Stockholm, Sweden.
E-mail: Ard.den.Reijer@riksbank.se

[§]Sveriges Riksbank, Monetary Policy Department, SE-103 37 Stockholm, Sweden.
E-mail: Patrik.Jonasson@riksbank.se

[¶]University of Oslo, Department of Economics. E-mail: Ragnar.Nymoen@econ.uio.no

modelling of aggregate product demand, interest rate setting, credit growth, the market foreign exchange and wage and price setting equations. Although MOSES is a short-term model, the concept of steady state nevertheless plays an important role in the shaping of the model's dynamic properties. MOSES is a highly restricted dynamic Simultaneous Equations Model (SEM) with a high degree of endogeneity. Proof of this endogeneity is that both public expenditure (a fiscal policy variable) and a number of foreign variables (GDP, prices, and interest rate) are modelled as endogenous variables. This is done in order to generate MOSES forecasts that are for all practical purposes automatically generated from given initial conditions (after the model has been estimated), which can then be compared with the results of other forecasting methods and models that are part of the forecast generating systems of a major forecasting institution like the Riksbank of Sweden. The model builds on the relevant theory for each market in order to achieve the best representation. The model is also based on structural and institutional characteristics of the Swedish economy, as opposed to more stylized theory-based models.

Figure 1 presents the main functional relationships in MOSES in a flow chart. The line with a single arrowhead show one-way causation and joint-causation is represented by lines with arrowheads at both ends.

MOSES is a model where almost all variables are endogenous. As seen in the flow chart, only the oil price ($SPOIL$), the electricity price (PE), the degree of accommodative labour market policy (captured by the labour market accommodation rate ($AMUN$), and the replacement rate (RPR)), are non-modelled variables.

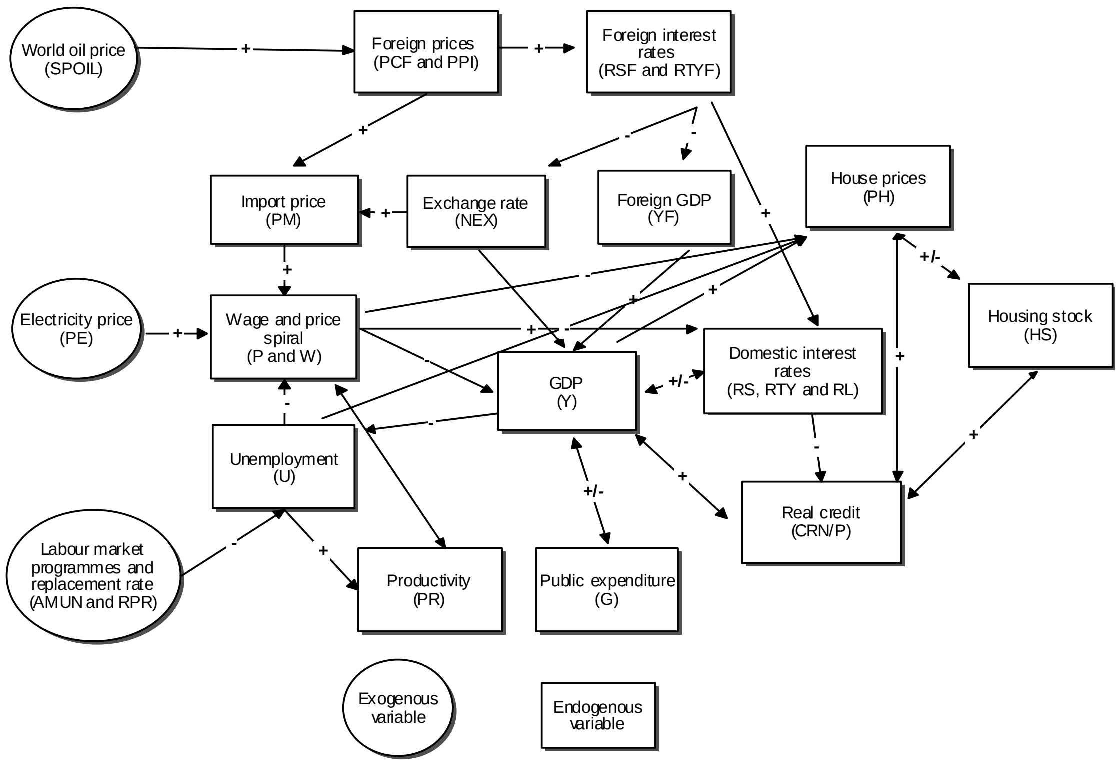

Figure 1: A flow chart of MOSES.

The upper part of the chart contains relationships for the "foreign sector". In the model, all these variables are caused by world oil prices. For example, higher energy prices leads to higher prices on foreign manufactures (PPI) and also to higher foreign consumer prices (PCF). These increases feed into the domestic wage-price spiral via the equation for import prices (PM). But the higher foreign prices (PCF) also affect foreign GDP (YF) in the short run, through their effect on foreign real interest rates (the money market rate (RSF) and the 10 year bond yield rate ($RTYF$)). As we have implemented the Taylor principle in foreign interest rate setting, an increase in foreign inflation leads to higher foreign real interest rates and a reduction in the growth rate of foreign GDP.

Increases in foreign prices, ceteris paribus, also lead to an appreciation of the nominal exchange rate, meaning that the pass-through of foreign prices on import prices and therefore on domestic wage and price setting is lowered through exchange rate adjustments. The supply side with the wage-price relationships (W and P) are strongly conditioned by import prices, since Sweden is a small open economy.

If domestic inflation increases, domestic interest rates will adjust upwards, first the "repo-rate" (RS), then the bond yield rate (RTY) and the interest rate on bank loans (RL). Because of the Taylor principle, the corresponding domestic real interest rates increases lead to reduced aggregate demand and GDP (Y). Note however, that because of flexible inflation targeting, there is joint causation between GDP and domestic interest rates in the medium-run time perspective (this is also marked by a +/- on the connector between interest rates and GDP. We have also marked a direct (and negative) influence from domestic inflation on GDP, and this occurs through the real exchange rate.

Real GDP is of course an important variable in the model. In addition to the real exchange rate and real interest rate, it is strongly conditioned by income abroad (YF), and public expenditure (G). Domestic GDP is also influenced by the growth of real credit (CRN/P), and in turn affects firms' and households' willingness to take on higher interest rates payments as a result of higher debt. Hence, there is a credit accelerator in the model. GDP growth is also important the evolution of the rate of unemployment (U), through an Okun's law relationship.

Labour productivity (PR) in the model provides the link between the different labour market channels and therefore also sums up the supply-side development, normally following the same positive trend as real wages, but also positively affected by the unemployment rate, in accordance with efficiency wage theories.

2.1 A simplified analytical exposition

MOSES covers a large number of markets, and the relevant dynamic relationships between these markets. MOSES is therefore a dynamic model of some complexity. Not counting the identities, MOSES has 20 equations. However, the core of MOSES is easily interpreted in line with most standard macro theories. For example, consider making the following standard theoretical simplifying assumptions: a closed economy, no public sector, a single interest rate, no debt, no housing market, no energy, no unemployment, productivity follows a stochastic trend, and first-order dynamics. Then the qualitative properties of MOSES can be represented by the following model:

$$\Delta p_t = a_{12}\Delta y_t - c_{11}\left[p - (w - pr) - \mu_1\right]_{t-1} \tag{1}$$

$$\Delta y_t = -c_{22}\left[y + \beta_{23}\left(R - \Delta p\right) - \mu_2\right]_{t-1} \tag{2}$$

$$\Delta R_t = -c_{33}\left[R_{t-1} - a_{31}\left(\Delta p_t - \overline{\Delta p}\right) - a_{32}\left(\Delta y_t - \overline{\Delta y}\right) - \mu_3\right] \tag{3}$$

$$\Delta\left(w - p - pr\right)_t = -c_{44}\left(w - p - pr + \mu_1\right)_{t-1} \tag{4}$$

$$\Delta pr_t = \mu_5 \tag{5}$$

where in (1) inflation Δp_t is caused by demand effects, represented by the growth rate of real output Δy_t, and real marginal labour costs $(w - p - pr)$.[1] The dynamics of real aggre-

[1]Throughout the paper lower case letters denote natural logarithms of variables, so $x_t \equiv \ln X_t$ and $\Delta x_t \approx \frac{X_t - X_{t-1}}{X_{t-1}}$.

gate demand Δy in (2) is driven by the real interest rate $(R - \Delta p)$, with μ_2 representing the average growth rate of real output. The interest rate R in (3) is set according to a Taylor rule, reacting to inflation deviating from its target $\left(\Delta p_t - \overline{\Delta p}\right)$, but specified in terms of output growth deviations from target $\left(\Delta y_t - \overline{\Delta y}\right)$ rather than potential output—which is not observable. The parameter μ_3 represents the natural rate of interest. The wage equation (4) is simply a stationary wage share, so $|c_{44}| < 1$, and μ_1 is the log of the long-run wage share. The model is closed by assuming that labour productivity follows a random walk with drift μ_5 in (5). To appreciate the simplifications made for ease of exposition, the MOSES econometric equivalents are given as equations (53), (54), (55), (57) and (64), respectively in the Appendix. Although simple, this standard theory model retains the qualitative aspects of MOSES. We will therefore refer to this theory-model representation when illustrating aspects of the model development below. For example, the theory behind the stylized price-wage model (1) and (4) is given in Section 4.1, with the general versions of the price-wage model given in (29) and (30).

2.2 An alternative graphical exposition

The model can also easily be interpreted within the standard dynamic aggregate supply and demand framework, AD-AS for short. Moreover, if we take into account that MOSES contains the relationship between the output-gap and the rate of unemployment (this is suppressed in (1) to (5)), we get the picture in Figure 2.

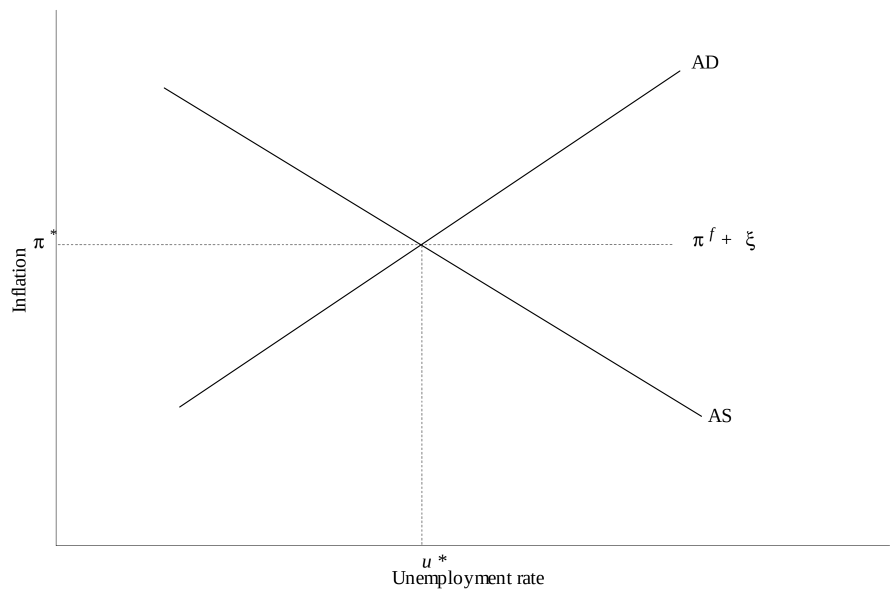

Figure 2: Equilibrium unemployment rate (u^*) and inflation rate (π^*) in a graphical representation of MOSES with the use of curves for aggregate demand (AD) and aggregate supply (AS) as functions of the rate of unemployment. π^f denotes the rate of inflation abroad, and ξ denotes the rate of currency depreciation.

The partial relationship between (log of) unemployment in period t, denoted u_t, and the domestic rate of inflation, π_t is shown as the increasing line, marked AD, in the figure. There are two main mechanisms behind the positive relationship. First, in an inflation targeting monetary policy regime, higher inflation leads to stronger real interest rates as a result of a higher policy interest rate. This reduces domestic demand and increases unemployment. Second, higher inflation usually leads to a higher real exchange rate, since the nominal exchange rate is typically not depreciated so much that the increase in π_t is offset completely. The slope of the AD curve is conditioned by the weights attributed to output/unemployment on the one hand, and inflation on the other, in the monetary policy response function. Specifically, a high weight on output/unemployment implies a steeper AD curve than a policy with little weight on output/unemployment, see e.g. Sørensen and Whitta-Jacobsen (2010).

The downward sloping line in the figure, marked AS for aggregate supply, illustrates that firms' price setting, and firm and union wage bargaining, lead to a lower rate of inflation if the overall rate of unemployment is increased. The AS curve in the figure looks like a conventional short-run Phillips curve but the underlying economic theory is based on wage-bargaining and monopolistic price setting as explained in e.g. Bårdsen and Nymoen (2003). Because the modelling behind the AS curve in Figure 2 is central to MOSES' properties, section 4.1 gives a more detailed exposition of that part of the model. With reference to Figure 2 we can already derive one important property, namely that in an equilibrium situation, with inflation equal to the inflation target, and with predetermined foreign inflation, both the rate of unemployment and the rate of currency depreciation are endogenously determined variables within MOSES.

3 Methodology

This section sets out the general methodology used in deriving a dynamic simultaneous econometric model (SEM) as MOSES, drawing upon Bårdsen et al. (2004) and Bårdsen and Nymoen (2009a).

Consider the two-dimensional system of differential equations

$$\frac{dy}{dt} = f(y, x) , \qquad x = x(t) , \tag{6}$$

for which $y_1 \to \bar{y}_1$ and $y_2 \to \bar{y}_2$ as $t \to \infty$. A linearized backward-difference approximation to the solution of the system of differential equations then gives the system in form of a Vector Autoregression (VAR), or a Vector Equilibrium Correction Model (VEqCM) [2], namely,

$$\begin{aligned}
\begin{pmatrix} \triangle y_1 \\ \triangle y_2 \end{pmatrix}_t &= \begin{pmatrix} -\alpha_{11}c_1 \\ -\alpha_{22}c_2 \end{pmatrix} + \begin{pmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{pmatrix} \begin{pmatrix} y_1 - \delta_1 y_2 \\ y_2 - \delta_2 y_1 \end{pmatrix}_{t-1} + \begin{pmatrix} \zeta_1 \\ \\ \zeta_2 \end{pmatrix}_{t-1} \\
&+ \frac{1}{2}\begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \begin{pmatrix} \Delta y_1 \\ \Delta y_2 \end{pmatrix}_{t-1} + \begin{pmatrix} \Delta\zeta_1 \\ \\ \Delta\zeta_2 \end{pmatrix}_{t-1} \\
&+ \frac{5}{12}\begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \begin{pmatrix} \Delta^2 y_1 \\ \Delta^2 y_2 \end{pmatrix}_{t-1} + \begin{pmatrix} \Delta_1^2\zeta \\ \\ \Delta_2^2\zeta \end{pmatrix}_{t-1} \\
&+ \frac{3}{8}\begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \begin{pmatrix} \Delta^3 y_1 \\ \Delta^3 y_2 \end{pmatrix}_{t-1} + \begin{pmatrix} \Delta_1^3\zeta \\ \\ \Delta_2^3\zeta \end{pmatrix}_{t-1} + \cdots .
\end{aligned} \tag{7}$$

with

$$\begin{aligned} c_1 &= (\bar{y}_1 + \delta_1 \bar{y}_2) , \quad \delta_1 = \tfrac{\alpha_{12}}{\alpha_{11}} \\ c_2 &= (\bar{y}_2 + \delta_2 \bar{y}_1) , \quad \delta_2 = \tfrac{\alpha_{21}}{\alpha_{22}} \end{aligned}$$

and ζ_i is the Lagrange form of the remainders in the Taylor approximation.

The VAR-representation is very general and consistent with a large class of underlying models. For example, following Fernandez-Villaverde et al. (2007), in compact notation

[2] See Bårdsen et al. (2004) for details.

the (log-linearised) equilibrium conditions of a large class of Dynamic Stochastic General Equilibrium (DSGE) models can be written as

$$\mathbf{F}E_t\mathbf{x}_{t+1}+\mathbf{G}\mathbf{x}_t+\mathbf{H}\mathbf{x}_{t-1}+\mathbf{J}\mathbf{e}_t=\mathbf{0}, \tag{8}$$

where $E_t = E(\cdot \mid I_t)$ is the expectation conditional on the available information set I_t, $\mathbf{x}_t$ is a vector of state variables and $\mathbf{e}_t$ is a vector of uncorrelated white noise shocks (e.g., shocks to technology and preferences). The elements in the coefficient matrices are non-linear functions of the underlying structural parameters in the DSGE model. If the conditions of Blanchard and Kahn (1980) are satisfied, the model has a unique stable solution

$$\mathbf{x}_t= \mathbf{A}\mathbf{x}_{t-1}+\mathbf{B}\mathbf{e}_t.$$

Adding a set of measurement equations relating the elements of $\mathbf{w}_t$ to a vector of observable variables $\mathbf{y}_t$ gives the state-space representation

$$\begin{aligned}\mathbf{x}_t&= \mathbf{A}\mathbf{x}_{t-1}+\mathbf{B}\mathbf{e}_t \\ \mathbf{y}_t&= \mathbf{C}\mathbf{x}_{t-1}+\mathbf{D}\mathbf{e}_t.\end{aligned} \tag{9}$$

If the number of observables equals the number of shocks and $\mathbf{D}^{-1}$ exists, a necessary and sufficient condition for invertibility of the moving average representation—so it is possible to recover the shocks $\mathbf{e}_t$ from the current and lagged values of the observables (see e.g., Watson, 1994)—is that the eigenvalues of $\mathbf{A} - \mathbf{B}\mathbf{D}^{-1}\mathbf{C}$ are strictly less than one in modulus (see Fernandez-Villaverde et al., 2007). If this condition is satisfied, $\mathbf{y}_t$ has the VAR representation

$$\mathbf{y}_t = \mathbf{C}\sum_{j=0}^{\infty}\left(\mathbf{A} - \mathbf{B}\mathbf{D}^{-1}\mathbf{C}\right)^j \mathbf{B}\mathbf{D}^{-1}\mathbf{y}_{t-j-1} + \mathbf{D}\mathbf{e}_t.$$

Further, as shown by Ravenna (2007), if all the endogenous state variables are observable and included in the VAR, the VAR representation is of finite order.[3] The VAR approximation to the DSGE model is therefore one restricted version of (6). In general, any system with a stable steady state can be given a linearized, discretized EqCM representation.

At this point two comments are in place. The first is that an econometric specification will mean a truncation of the polynomial both in terms of powers and lags. Diagnostic testing is therefore imperative to ensure a valid local approximation, and indeed to test that the statistical model is valid, see Hendry (1995) and Spanos (2008). As an example, consider a linear underlying model, so $\zeta_i = 0$, and assume that higher order dynamics can be ignored. The system (7) then simplifies to

$$\begin{pmatrix} \triangle y_1 \\ \triangle y_2 \end{pmatrix}_t = \begin{pmatrix} -\alpha_{11}c_1 \\ -\alpha_{22}c_2 \end{pmatrix} + \begin{pmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{pmatrix}\begin{pmatrix} y_1 - \delta_1 y_2 \\ y_2 - \delta_2 y_1 \end{pmatrix}_{t-1}.$$

The second comment is that the framework allows for flexibility regarding the form of the steady state. The standard approach in DSGE-modelling has been to filter the data, typically using the so-called Hodrick-Prescott filter, to remove trends, hopefully achieving stationary series with constant means, and then work with the filtered series. Another approach is to impose the theoretical balanced growth path of the model on the data, expressing all series in terms of growth corrected values. However, an alternative approach is to estimate the balanced growth paths in terms of finding the number of common trends and identifying and estimating cointegrating relationships. The present approach allows for all of these interpretations.

[3] In general, however, the VAR is of infinite order (corresponding to a VARMA representation).

To illustrate the approach in terms of cointegration, consider real wages to be influenced by productivity, as in many theories and also in the model of section 2.1. To be specific, consider the price-wage model that will be used in section 4.1. Assume that the logs of the real wage $rw_t = (w-p)_t$ and productivity pr_t are each integrated of order one, but found to be cointegrated, so

$$rw_t \sim I(1), \Delta rw_t \sim I(0) \tag{10}$$

$$pr_t \sim I(1), \Delta pr_t \sim I(0) \tag{11}$$

$$(rw - \beta pr)_t \sim I(0). \tag{12}$$

Letting $y_{1t} \equiv (rw - \beta pr)_t$ and $y_{2t} \equiv \Delta pr_t$ then gives

$$\begin{pmatrix} \triangle(rw-\beta pr) \\ \Delta^2 pr \end{pmatrix}_t = \begin{pmatrix} -\alpha_{11}c_1 \\ -\alpha_{22}c_2 \end{pmatrix} + \begin{pmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{pmatrix} \begin{pmatrix} (rw-\beta pr) - \delta_1 \Delta pr \\ \Delta pr - \delta_2(rw-\beta pr) \end{pmatrix}_{t-1}$$

or multiplied out:

$$\begin{aligned} \triangle rw_t &= -\alpha_{11}c_1 + \alpha_{11}(rw-\beta pr)_{t-1} + \beta\Delta pr_t - \alpha_{12}\Delta pr_{t-1} \\ \Delta pr_t &= -\alpha_{22}\left(\overline{pr} + \frac{\alpha_{21}}{\alpha_{22}}\overline{rw}\right) + (\alpha_{22}-1)\,\Delta pr_{t-1} - \alpha_{21}(rw-\beta pr)_{t-1} \end{aligned}$$

So if $\alpha_{21} = 0$ and $|\alpha_{22} - 1| < 1$ the system simplifies to the familiar exposition of a bivariate cointegrated system with pr being weakly exogenous for β, giving rise to a richer version of the price-wage model of Section 2.1:

$$\begin{aligned} \triangle rw_t &= -\alpha_{11}c_1 + \alpha_{11}(rw-\beta pr)_{t-1} + \beta\Delta pr_t - \alpha_{12}\Delta pr_{t-1} \\ \Delta pr_t &= -\alpha_{22}\,\overline{pr} + (\alpha_{22}-1)\,\Delta pr_{t-1}, \end{aligned}$$

with the common stochastic trend coming from productivity and the wage-share being stationary.

3.1 Aspects in choice of model

As we have seen, many kinds of models can be well represented by a VAR as a statistical system. The choice of model is therefore very much dependent upon its intended use, and many considerations come into play. However, in developing models to be used both for policy analysis and forecasting, we have at least found the following criteria useful:

1. A model should be highly endogenous, so it is easy to forecast with;
2. it should use the relevant theory for each market, so it is interpretable;
3. it should contain institutional features, so it is relevant for policy analysis;
4. it should be data- and theory-coherent for all restrictions, so it is reliable;
5. it should be as restricted as data will allow, so it is efficient;
6. it should fit the data—see Granger (1992).

We have used these criteria in developing MOSES as a dynamic SEM. Note that neither DSGEs nor Structural VARs are excluded from these criteria in principle, altough most existing specimens will not pass all the items on this list. It should be noted, however, that both DSGEs and SVARs can be interpreted as specific versions of a SEM. Only experience and evidence that accrues over time will answer which model will be most useful. In Section 7 we therefore compare the performance of MOSES to both a DSGE model and a Structural VAR.

3.2 From a discretized and linearized cointegrated VAR representation to a dynamic SEM in three steps

We now set out the steps used in deriving a model from a statistical system. We will keep this section brief, as comprehensive treatments can be found in many places—for example in Hendry (1995), Johansen (1995, 2006), Juselius (2007), Garratt et al. (2006), and Lütkepohl (2006)

3.2.1 First step: the statistical system

Our starting point for identifying and building a macroeconometric model is to find a linearized and discretized approximation as a data-coherent statistical system representation in the form of a cointegrated VAR

$$\Delta \mathbf{z}_t = \mathbf{c} + \Pi \mathbf{z}_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta \mathbf{z}_{t-i} + \mathbf{e}_t, \tag{13}$$

with independent Gaussian errors $\mathbf{e}_t$ as a basis for valid statistical inference about economic theoretical hypotheses.

The purpose of the statistical model (13) is to provide the framework for hypothesis testing, the inferential aspect of macroeconometric modelling. However, it cannot be postulated directly, since the cointegrated VAR itself rests on assumptions. Hence, validation of the statistical system is an essential step: Is a model which is linear in the parameters flexible enough to describe the fluctuations of the data? What about the assumed constancy of parameters, does it hold over the sample that we have at hand? And the Gaussian distribution of the errors, is that a tenable assumption so that (13) can supply the inferential aspect of modelling with sufficient statistics. The main intellectual rationale for the model validation aspect of macroeconometrics is exactly that the assumptions of the statistical system requires separate attention.

As pointed out by Garratt et al. (2006), the representation (13) does not preclude forward-looking behaviour in the underlying model, as rational expectations models have backward-looking solutions.

Even with a model which for many practical purpose is small scale it is usually too big to be formulated in "one go" within a cointegrated VAR framework. Hence, model (13) for example is not interpretable as one rather high dimensional VAR, with the (incredible) long lags which would be needed to capture the complicated dynamic interlinkages of a real economy. Instead, as explained in Bårdsen et al. (2003), our operational procedure is to partition the (big) simultaneous distribution function of markets and variables: prices, wages, output, interest rates, the exchange rate, foreign prices, and unemployment, etc. into a (much smaller) simultaneous model of wage and price setting—the labour market—and several sub-models of the rest of the macro economy. The econometric rationale for specification and estimation of single equations, or of markets, subject to exogeneity conditions, before joining them up in a complete model is discussed in Bårdsen et al. (2003), and also in (Bårdsen et al., 2005, Ch. 2).

3.2.2 Second step: the overidentified steady state

The second step of the model building exercise will then be to identify the steady state, by testing and imposing overidentifying restrictions on the cointegration space:

$$\Delta \mathbf{z}_t = \mathbf{c} + \alpha \beta' \mathbf{z}_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta \mathbf{z}_{t-i} + \mathbf{e}_t,$$

thereby identifying both the exogenous common trends, or permanent shocks, and the steady state of the model.

Even though there now exists a literature on identification of cointegration vectors, it is worthwhile to reiterate that identification of cointegrating vectors cannot be data-based. Identifying restrictions have to be imposed *a priori*. It is therefore of crucial importance to have a specification of the economic model and its derived steady state before estimation. Otherwise we will not know what model and hypotheses we are testing and, in particular, we could not be certain that it was identifiable from the available data set

3.2.3 Third step: the dynamic SEM

The final step is to identify the dynamic structure:

$$\mathbf{A}_0\Delta\mathbf{z}_t = \mathbf{A}_0\mathbf{c} + \mathbf{A}_0\alpha\beta'\mathbf{z}_{t-1} + \sum_{i=1}^{k}\mathbf{A}_0\Gamma_i\Delta\mathbf{z}_{t-i} + \mathbf{A}_0\mathbf{e}_t,$$

by testing and imposing overidentifying restrictions on the dynamic part—including in principle the forward-looking part—of the statistical system.

3.3 Automatic model selection

General to specific (Gets) modelling strategies has been advocated and debated over several decades. One advantage of Gets compared to specific to general modelling is that it lets itself to computer automatization. Good algorithms for Gets modelling have been shown to be able to retrieve a true model with great regularity, if it is situated within the general statistical model that marks the starting point of the selection process, see Hoover and Perez (1999) and Hendry and Krolzig (1999).

Following Doornik (2009), the essential steps in an automatized Gets procedure can be summarized as follows:

1. Start from general statistical system (GUM) based (at least) on previous findings and available theory.

2. Check GUM captures essential characteristics of data: ensures valid inferences.

3. Eliminate insignificant variables to reduce complexity:

   (a) diagnostic checks on validity of reductions

   (b) ensures congruence of final model.

4. Use tree search to avoid path-dependence.

5. Use backtesting to restrict information loss to user-determined level.

In the following we refer to this as Autometrics, which has been an essential ingredient in building MOSES. From a practical perspective, we note in particular that when modelling seasonally adjusted data, changes in the method of seasonal adjustment (decided "from outside") can affect all data series over the whole sample. To adapt the model structure to the new measurement system is time consuming with manual modelling. Autometrics makes remodelling practically feasible even with frequent data revisions due to seasonally adjusted data.

Despite the automatization in model specification, good judgement and economic theory remain essential when doing Gets modelling with a computer programme. For example, the larger the GUM is, the larger the probability of retaining some effects by chance. On the other hand a too small GUM can entail omission of key variables from the outset.

This means that prior analysis using theory and institutional and historical knowledge are essential for choice of relevant variables, functional form, indicators etc. in the GUM. If available, previous evidence needs to be addressed to ensure encompassing, and finally there remains also a central role for theory in 'prior simplification'.

Autometrics is available for systems, but when building a realistic model, the dimensions are too big for one system. We will therefore typically model blocks (not necessarily single equations though) of the complete model and then put them together at the end. Blockwise modelling is easy to criticize, but difficult to beat in practice. One explanation is that even though there are many interactions between the different markets and decision processes that go into a macro model, a relevant model representation of each market can be established without taking all these interactions into account, in fact it is often a necessity. Trying to model everything in "one go" on the other hand may lead to a less relevant model structure.

4 Aspects in the design of MOSES

The theoretical framework defines many premises for a macroeconometric model. In the case of MOSES care has been taken to build on theories that, though necessarily abstract and simplified, have a high degree of relevance for the Swedish economy. In this section we therefore give two examples of such considerations when designing and building MOSES. We start with the theoretical background for price-wage process of the stylized model of Section 2.1.

4.1 The wage-price spiral (the aggregate supply relationship)

The model of the wage-price spiral is of special relevance, since it delivers a set of premises for an inflation targeting central bank. The variables in the model we formulate (in logarithms) are: wages per hour, denoted w, a price level variable for the producer price, q, the domestic consumer price index, p, import prices in domestic currency, pm, average labour productivity, pr, and the rate unemployment, u.

4.1.1 Optimal price and wage levels

As is custom, we refer to the the wages and prices that firms and unions would decide if there were no costs or constraints on adjustment, as the optimal or target values of prices and wages. Another interpretation, following from the essentially static nature of these models, the optimal prices are those that would prevail in a hypothetical completely deterministic steady-state situation.

Specifically, we have the following two theoretical propositions of wage and price setting:

$$q^f = m_q + w - pr - \vartheta u, \tag{14}$$

with $m_q > 0$ and $\vartheta \leq 0$, and

$$w^b = m_w + q + \omega\,(p - q) + \iota pr - \varpi u, \tag{15}$$

with $m_w > 0$, $0 \leq \omega \leq 1$, $0 < \iota \leq 1$, $\varpi \geq 0$. The variable q^f in (14) refers to the theoretical price determined by monopolistic firms in a situation characterized by known and stable growth in the hourly wage, and in labour productivity. From the profit maximizing conditions it is implied that the mark-up coefficient m_q is positive, because firms choose a point on the elastic part of the demand curve (where the demand elasticity is larger than one in absolute value). We follow custom and approximate marginal labour costs with $w - pr - \vartheta u$, where pr is average labour productivity. With reference to Okun's law, we interpret the rate of unemployment as a replacement for capacity utilization. The case of

$\vartheta = 0$ is so often considered as the relevant case that it has earned its own name, namely *normal cost pricing*.

Turning to equation (15), the variable w^b denotes the theoretical concept of the "bargained wage" as the equation is derived from a theory of wage bargaining, see e.g., (Bårdsen et al., 2005, Ch. 5). The right hand side contains the variables that are expected to have the potential of systematic influence on the bargained wage. The producer price q and productivity pr are central variables in the model of wage formation. This is well established theoretically, see e.g., Nymoen and Rødseth (2003) and Forslund et al. (2008), and these variables are also found to be main empirical determinants of the secular growth in wages in bargaining based systems. Based on theory and the empirical evidence, we expect the elasticity ι to be close to one. The elasticity of q has already been set to unity with reference to homogeneity of degree one with respect to nominal variables.

The impact of the rate of unemployment on the bargained wage is given by the elasticity $-\varpi \leq 0$. Blanchflower and Oswald (1994) provide evidence for the existence of an empirical law that the value of ϖ is 0.1, which is the slope coefficient of their *wage-curve*. Other authors instead emphasize that the slope of the wage-curve is likely to depend on the level of aggregation and on institutional factors. For example, one influential view holds that economies with a high level of coordination and centralization are expected to be characterized by a more sensitive responsiveness to unemployment (a higher ϖ) than uncoordinated systems, that give little incentive to solidarity in wage bargaining, cf, (Layard et al., 2005, Ch. 8).

Finally, equation (15) is seen to include the variable $(p-q)$, called the wedge (between the producer and the consumer real wage). The elasticity of the wedge is denoted ω in (15). Theoretically, the status of the wedge is less well micro founded than the other variables in (15). In fact, one main implication of the theory of collective bargaining (i.e., between labour union and profit maximizing firms) is that the consumer price, p, plays no role in determining the bargaining outcome. The crux of the argument is that wage bargaining is first and foremost about sharing of the valued-added created by capital and labour, all other considerations are of secondary importance in that theory, see Forslund et al. (2008). This implies $\omega = 0$ in (15).

However, it is not clear that the bargaining model is equally relevant for understanding wage setting in all sectors of the economy. In the service sectors, where unions may have little bargaining power, wage setting may be dominated by so called efficiency wage considerations. Interestingly, efficiency wage theory has qualitatively the same implications as the bargaining model. Equation (15) is consistent with both theories, but the hypothesized magnitude of the coefficients are different: The efficiency wage model predicts a larger role for cost of living considerations, meaning that $\omega > 0$ is characteristic of efficiency wage models, and a smaller effect of productivity, so $\iota < 1$ may seen as typical in the efficiency wage interpretation.

4.1.2 Identification and cointegration

We assume that both pr_t and pm_t are unit-root processes with positive and constant expected growth rates. This is a simple and relevant way of modelling the positive trends that dominate the actual time series of both productivity and import prices. Hence in a common notation $pr_t \sim I(1)$ and $pm_t \sim I(1)$. For the rate of unemployment, u_t, we maintain stationarity throughout the paper (but with the understanding that deterministic regime shifts have been filtered out). We denote this $u_t \sim I(0)$.

We first use (15) to define the bargained *real* wage rw^b as

$$rw^b \equiv w^b - q = m_w + \omega\,(p - q) + \iota pr - \varpi u. \tag{16}$$

Similarly, (14) can be used to define the targeted *real* wage from the firms' point of view as:

$$rw^f \equiv w - q^f = -m_q + pr + \vartheta u. \tag{17}$$

The expressions for the two (conflicting) targeted real wages in (16) and (17) can be used to define the stochastic variables rw_t^b and rw_t^f by replacing q, p, pr and u by their observable counterparts q_t, p_t, pr_t and u_t, namely

$$rw_t^b = w_t^b - q_t = m_w + \omega\,(p_t - q_t) + \iota pr_t - \varpi u_t, \tag{18}$$

and

$$rw_t^f \equiv w_t - q_t^f = -m_q + pr_t - \vartheta u_t. \tag{19}$$

which shows that the wedge variable is proportional to the real-exchange rate defined as $pm_t - q_t$.

Next, defining the firms' real wage "gap",

$$\begin{aligned} ecm_t^f &= rw_t - rw_t^f = q_t^f - q_t \\ &= w_t - q_t - pr_t - \vartheta u_t + m_q, \end{aligned} \tag{20}$$

and the workers' real wage "gap",

$$\begin{aligned} ecm_t^b &= rw_t - rw_t^b = w_t - w_t^b \\ &= w_t - q_t - \omega(p_t - q_t) - \iota pr_t + \varpi u_t - m_w, \end{aligned} \tag{21}$$

give the solutions for wages and producer prices as

$$w_t = q_t + \omega(p_t - q_t) + \iota pr_t - \varpi u_t + m_w + ecm_t^b \tag{22}$$

$$q_t = w_t - pr_t - \vartheta u + m_q - ecm_t^f. \tag{23}$$

In MOSES we do not include q_t and p_t as separate variables. Defining the consumer price index as:

$$p_t = \phi q_t + (1 - \phi) pm_t, \tag{24}$$

(22) and (23) can be re-expressed in terms of w_t and p_t only:

$$\begin{aligned} w_t = m_w &+ \frac{1 - \omega(1 - \phi)}{\phi} p_t + \iota pr_t - \varpi u_t \\ &- \frac{1 - \omega(1 - \phi)}{\phi} pm_t + ecm_t^b, \end{aligned} \tag{25}$$

$$p_t = -\phi m_f + \phi(w_t - pr_t) + \phi\vartheta + (1 - \phi) pi_t - \phi ecm_t^f. \tag{26}$$

that implicitly implies non-linear cross-equation restrictions in terms of ϕ.

By viewing (25) and (26) as two simultaneous equations, it is clear that the system is unidentified in general, (Bårdsen et al., 2005, Ch. 5.4). However, the high level of aggregation of MOSES makes it relevant to set $\omega = 1$. This restriction implies that the model does not distinguish between the aggregate product and consumer price in wage setting. Together with an assumption about normal cost pricing in the aggregated price relationship, $\vartheta = 0$, the restriction $\omega = 1$ makes (25) and (26) identified with reference to the order condition. In this case,the two identified long-run equations can be re-written as:

$$w_t = m_w + p_t + \iota pr_t - \varpi u_t + ecm_t^b, \tag{27}$$

$$p_t = -\phi m_f + \phi(w_t - pr_t) + (1 - \phi) pm_t - \phi ecm_t^f. \tag{28}$$

If the economic theory is empirically relevant, both ecm_t^b and ecm_t^f are stationary $I(0)$ variables. Hence, the assumptions stated above imply that (27) and (28) are two cointegrating relationships.

4.1.3 Equilibrium correction model of the wage-price spiral

Equilibrium correction dynamics are implied by cointegration, and we can therefore write down the following equilibrium correction model for wages and prices[4]:

$$\Delta w_t = c_w + \psi_{wp}\Delta p_t - \varphi u_{t-1} - \theta_w ecm^b_{t-1} + \varepsilon_{w,t},$$
$$\Delta p_t = c_p + \psi_{pw}\Delta w_t + \psi_{ppm}\Delta pm_t + \varsigma u_{t-1} + \theta_p \phi ecm^f_{t-1} + \varepsilon_{q,t}.$$

If we use the expressions for ecm^b_t and ecm^f_t, we obtain a dynamic system that can represent the supply-side of MOSES:

$$\Delta w_t = k_w + \psi_{wp}\Delta p_t - \theta_w(w_{t-1.} - p_{t-1} - \iota pr_{t-1}) + (\theta_w \varpi + \varphi)\, u_{t-1} + \varepsilon_{w,t}, \tag{29}$$
$$\Delta p_t = k_w + \psi_{pw}\Delta w_t + \psi_{ppm}\Delta pm_t + \theta_p(w_{t-1} - p_{t-1} - pr_{t-1}) \tag{30}$$
$$+ \theta_p(1-\phi)(pm_{t-1} - p_{t-1}) + (\theta_q \vartheta + \varsigma)\, u_{t-1} + \varepsilon_{q,t},$$

where all the derivative coefficients take non-negative values.

The coefficient θ_w in (29) is a key parameter. In the case when the wage bargaining/efficiency wage model give a cointegrating relationship, $\theta_w > 0$ is implied. The only logically consistent value of the parameter φ is then zero. Hence we use the following convention, see Kolsrud and Nymoen (1998):

$$\text{Wage bargaining model: } \theta_w > 0\ , \varpi > 0 \text{ and } \varphi = 0. \tag{31}$$

We make a similar distinction for firms' price-setting, i.e., when the long-run price setting equation is a cointegration relationship, we have:

$$\text{Price mark-up model: } \theta_p > 0 \text{ and } \varsigma = 0 \tag{32}$$

Equations (54) and (53) in the Appendix show the estimated version of (29) and (30). Those results show that the estimated θ_w and θ_p are both statistically significant different from zero. This indicates a well controlled wage-price spiral in the current Swedish economy, which is a favourable premise for inflation targeting.

4.1.4 Phillips curve model of the wage-price spiral.

The default specification of the wage-price spiral in MOSES is the wage bargaining/price mark-up model given above. An alternative specification is defined by

$$\text{Wage Phillips curve model: } \theta_w = 0 \text{ and } \varphi > 0. \tag{33}$$

$$\text{Price Phillips curve model: } \theta_q = 0 \text{ and } \varsigma > 0, \tag{34}$$

This yields a price Phillips curve with an effect of u_{t-1} directly on Δp_t (since we now have $\varsigma > 0$), and a wage Phillips curve, since $\varphi > 0$ in this specification of the supply side. With suitable restrictions on the short-run dynamics of the two equations, a specification with a vertical long-run AS schedule results.

Although a Phillips-curve version of MOSES is easy to implement and it may be seen as more representative of standard macroeconomic models than the default version is, care must be taken to avoid misguided policy advice. For example, if : $\theta_w = 0$ and $\theta_q = 0$

[4] For the coefficients ψ_{wq}, ψ_{qw} and ψ_{wp}, ψ_{qpi}, the non-negative signs are standard in economic models. Negative values of θ_w and θ_q imply explosive evolution in wages and prices (hyperinflation), which is different from the low to moderately high inflation scenario that we have in mind for this paper.

are imposed (despite the evidence), the model's properties may change fundamentally, as Bårdsen and Nymoen (2009b) show for a model of the US economy. In particular the speed of adjustment and the degree of stability of the wage-price spiral are affected, which may lead to advise of sharper interest rate response than would be optimal in the light of the empirically validated model version, see Akram and Nymoen (2009) for an analysis of optimal interest rate setting in a macroeconometric model for Norway.

4.2 Monetary and fiscal policy

As noted above MOSES contains a large number of relevant functional relationships in the Swedish macroeconomy. Two important policy instruments are also endogenized in MOSES: the short term interest rate (monetary policy) and government consumption (fiscal policy).

4.2.1 Monetary policy

The 'repo' interest rate RS is set according to a standard monetary response function for a small open economy, targeting underlying inflation π_{Rt} and output growth $\dot{Y}_t$ in addition to following the foreign interest rate RSF.[5] Allowing for interest rate smoothing, this results in the general specification

$$RS_t = \alpha_1 R_{t-1} + \alpha_2 RSF_t + \alpha_3 RSF_{t-1} + \alpha_4 \left(\pi_{FRt} - \overline{\pi_{FRt}}\right) + \alpha_5 \left(\dot{Y}_t - \overline{\dot{Y}_t}\right)$$

This Taylor rule can trivially be rewritten in EqCM-form as:

$$\Delta RS_t = -\left(1-\alpha_1\right)\left[R_{t-1} - \left(\frac{\alpha_2+\alpha_3}{1-\alpha_1}\right) RSF_{t-1} - \left(\frac{\alpha_4}{1-\alpha_1}\right)\left(\pi_{FRt} - \overline{\pi_{FRt}}\right) - \left(\frac{\alpha_5}{1-\alpha_1}\right)\left(\dot{Y}_t - \overline{\dot{Y}_t}\right)\right] + \alpha_2 \Delta RSF_t.$$

The corresponding estimated interest rate response function, reproduced from equation (64) in the appendix, is

$$\Delta RS_t = -\underset{(0.023)}{0.17}\left[RS_{t-1} - RSF_{t-1} - 1.4\left(\pi_{FRt} - 2\right) - 0.2\dot{Y}_t\right] + \underset{(0.071)}{0.75}\,\Delta RSF_t, \quad (35)$$

This equation obeys the Taylor principle, in the sense that, over a few periods of time, an autonomous increase in inflation of one percentage point leads to an increase in the 'repo' interest rate by more than one percentage point (the real interest rate thus increases). As is well known, many theoretical models require that the Taylor principle applies within the period of the shock, otherwise the inflation process will become de-stabilized. According to the properties of MOSES, this analysis does not carry over to the Swedish economy. Because of e.g., equilibrium correction in wage and price setting, changes in the interest rate setting may be relatively gradual without undermining nominal stability of the inflation target.

4.2.2 Fiscal policy

Turning to fiscal policy, we start from the premise that to make MOSES produce internally consistent conditional forecasts, fiscal policy should be endogenous, since otherwise an important feed-back mechanism of the Swedish economy is left unmodelled. To motivate

[5] Underlying inflation is defined as $\pi_{FRt} \equiv 100\frac{\Delta_4 PFR_t}{PFR_{t-4}}$, where PFR_t is the consumer price index corrected for interest rate movements.

the discussion of alternatives, we start by establishing a common framework based on the fiscal budget identity in nominal values and in annual terms:

$$G_t + T_t - \tau_t P_t Y_t = B_t - (1 + RTY_t) B_{t-1},$$

where G_t denotes nominal government consumption plus nominal government investment, T_t denotes nominal social security transfers, and τ_t symbolizes the unobserved policy tax rate, consisting of wage taxes, social contribution taxes and value added taxes. The stock of nominal government debt is denoted B_t, and RTY_t symbolizes the bond rate.

With tildes denoting the variables expressed in ratios of nominal GDP, so $\tilde{B}_t \equiv \frac{B_t}{P_t Y_t}$, $\tilde{T}_t \equiv \frac{T_t}{P_t Y_t}$, and $\tilde{G}_t \equiv \frac{G_t}{P_t Y_t}$, the primary deficit $-\tilde{S}_t \equiv \left(\tilde{G}_t + \tilde{T}_t\right) - \tau_t$ is financed by debt changes:

$$-\tilde{S}_t = \tilde{B}_t - \frac{1 + RR_t}{1 + \dot{Y}_t} \tilde{B}_{t-1}, \tag{36}$$

where $RR_t \equiv \frac{1+RTY_t}{1+\pi_t}$ is the real interest rate with the inflation rate entering as π_t and the real GDP growth as $\dot{Y}_t$.[6]

The debt remains constant—on it's steady state level $\tilde{B}_t = \tilde{B}_{t-1} = \tilde{B}^*$—if the surplus equals

$$\tilde{S}_t = \tilde{B}^* \left(\frac{RR_t - \dot{Y}_t}{1 + \dot{Y}_t} \right).$$

So if economic growth rates are higher than the real interest rates on debt, continuous deficits are consistent with debt stabilization. This is therefore one of the key issues to be analyzed by the model, both for forecasting and for economic policy analysis.

To produce precise and credible forecasts, the fiscal policy rule must fit the data as well as reflect the Swedish budgetary policy. For forecasting purposes, in particular the interplay between GDP and public expenditure will be of paramount importance, since it plays a large role in the development of GDP.

The fiscal rules implemented in Sweden consists of three parts:

1. A surplus target for general government
2. an expenditure ceiling for central government
3. a balanced budget requirement for municipalities and county councils.

The surplus target for general government was introduced in 2000 and is quantified as 1% over the business cycle. The expenditure ceiling was introduced in 1997 and is fixed 3 years in advance based on being in line with long term sustainable finances and falling slightly as a GDP-ratio. Due to the balanced budget requirements we do not consider municipalities and counties explicitly in the following, but focus on the targets of central- and general government.

Following Claeys (2008), a standard reaction function capturing these aspects in log-linear form is

$$\tilde{s}_t^* = \tilde{s}^* + \gamma \left(y_t^e - y_t^*\right) + \theta \left(\tilde{b}_t - \tilde{b}^*\right)$$

where $\tilde{s}_t^*$ is the surplus target $\tilde{s}^*$ its long term level, so $\tilde{s}^* = \ln 0.01$ in the present case, and $(y_t^e - y_t^*)$ are expected deviations of output from the output target, which must be put into an operational form below, for example with factor analysis. Allowing for implementation lags then suggests a simple feedback rule, in stylized form:

$$\tilde{s}_t = \rho_s \tilde{s}_{t-1} + (1 - \rho) \tilde{s}_{t-1}^* + \varepsilon_t,$$

[6] We are using that $\frac{(1+R_t)B_{t-1}}{P_t Y_t} = \frac{(1+R_t)B_{t-1}}{P_{t-1}Y_{t-1}} \times \frac{P_{t-1}Y_{t-1}}{P_t Y_t} = \tilde{B}_{t-1}\left(\frac{(1+R_t)P_{t-1}Y_{t-1}}{(1+\pi_t)\left(1+\dot{Y}_t\right)P_{t-1}Y_{t-1}}\right) = \frac{1+RR_t}{1+\dot{Y}_t}\tilde{B}_{t-1}$.

using either a linear or a log-linear specification. For later use, note that this implementation can be trivially rewritten in equilibrium correction form (EqC)

$$\Delta\tilde{s}_t = -\left(1-\rho_s\right)\left(\tilde{s}_{t-1}-\tilde{s}^*_{t-1}\right)+\varepsilon_t. \tag{37}$$

An implementation of endogenous fiscal policy would then interact with the aggregate demand equation, again here in a highly stylized form:

$$\Delta y_t = \beta\Delta\tilde{s}_t - \left(y_{t-1}-y^*_{t-1}\left(\tilde{s}_{t-1}\right)\right) \tag{38}$$

forming a (possibly simultaneous) vector EqC system.

One possibility is to split (37) into separate rules for the three components

$$\tilde{g}_t = \rho_g\tilde{g}_{t-1} + \left(1-\rho_g\right)\left[\tilde{g}^* - \gamma_g\left(y^e_t - y^*_t\right)\right] + \varepsilon^g_t \tag{39}$$

$$\tilde{t}_t = \rho_t\tilde{t}_{t-1} + \left(1-\rho_t\right)\left[\tilde{t}^* - \gamma_t\left(y^e_t - y^*_t\right)\right] + \varepsilon^t_t \tag{40}$$

$$\tau_t = \rho_\tau\tau_{t-1} + \left(1-\rho_\tau\right)\left[\tau^* + \upsilon\left(\tilde{b}_{t-1}-\tilde{b}^*\right)\right] + \varepsilon^\tau_t \tag{41}$$

and to estimate the three rules as a system. In particular, note the endogeneity of Y in (37) through the ratio specification. The ratios in (37) must therefore be handled through identities as

$$\tilde{G}_t \equiv \frac{G_t}{P_t \times Y_t\left(\tilde{S}_t\right)} \text{ and } \tilde{T}_t \equiv \frac{T_t}{P_t \times Y_t\left(\tilde{S}_t\right)}. \tag{42}$$

A less ambitious, but possibly more robust, alternative chosen here is therefore to focus on a logs of levels specification of (39) with generalized dynamics, since we use quarterly data, and in constant prices:

$$\delta_G\left(L\right)\Delta g_t = -\left(1-\rho_G\right)\left(g_{t-1}-g^*_{t-1}\right) + \delta_y\left(L\right)\Delta y_t \tag{43}$$

where $G^*_t = G^* \times \left(\frac{G}{Y^\delta}\right)_t$, $0<\delta<1$. Such a specification is in line with the budget ceiling requirement of a falling $\frac{G}{Y}$ ratio as described as part of the official fiscal policy. We have done a full simultaneous system specification search of (38) and (43), resulting in the specification for (43) reported in (61) in the Appendix, and reproduced here:

$$\Delta g_t = -\underset{(0.06)}{0.35}\left(g_{t-4}-0.25y_{t-5}\right) - \underset{(0.057)}{0.17}\Delta_2 g_{t-1} - \underset{(0.07)}{0.21}\Delta y_{t-4} + \underset{(0.53)}{3.1}$$

with fiscal policy responding to GDP with a lag.

5 Dynamic properties of MOSES

This section looks at some dynamic properties of MOSES evaluated by dynamic simulations.

5.1 Adjustment speed and steady-state

As noted above, the steady-state properties of a dynamic model are of relevance also if the operational use of the model will be for short-run forecasting and analysis. This is because departures from steady-state equilibria have an influence on the dynamic solution over the relevant short time horizon. From a practical perspective it is also interesting whether the adjustment speeds of the model solution, towards the steady-state, is slow or relatively fast. Very slow adjustment speed means that the steady-state equilibrium has little influence on the dynamic solution for the models endogenous variable, while relatively fast adjustment speed suggest the opposite. Since an econometric model combines *a priori* theoretical information with data based modelling, and since a good part of the *a priori* information is contained in the model's steady-state relationships, the overall speed of adjustment of a model is a qualitative sign about the value added of an econometric model compared to a pure multivariate statistical forecasting model for example.

We can illustrate these points by looking at the solution of the linear model

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 x_{t-1} + \alpha y_{t-1} + \varepsilon_t \tag{44}$$

for a single endogenous variable y_t, and x_t is exogenous. ε_t is a random shock term with mathematical expectation zero.

As always, a particular solution of a dynamic model, is based on explicit assumptions about the unmodelled terms. Since the issue here is adjustment speed, we set x_t and ε_t equal to their long-run means m_x and 0. With y_0 denoting the initial condition the solution becomes

$$y_t = (\beta_0 + Bm_x)\sum_{s=0}^{t-1}\alpha^s + \alpha^t y_0, \;\; t = 1, 2, ... \tag{45}$$

The condition

$$-1 < \alpha < 1 \tag{46}$$

is the necessary and sufficient condition for the existence of a globally asymptotically *stable* solution. The stable solution has the characteristic that asymptotically there is no trace left of the initial condition y_0. From (45) we see that as the distance in time between y_t and the initial condition increases, y_0 has less and less influence on the solution. When t becomes large (approaches infinity), the influence of the initial condition becomes negligible. Since $\sum_{s=0}^{t-1}\alpha^s \rightarrow \frac{1}{1-\alpha}$ as $t \rightarrow \infty$, we have asymptotically:

$$y^* = \frac{(\beta_0 + Bm_x)}{1-\alpha} \tag{47}$$

where y^* denotes the stead-state equilibrium of y_t. As stated, y^* is independent of y_0. Using this result in (45), and next adding and subtracting $(\beta_0 + Bm_x)\alpha^t/(1-\alpha)$ on the right hand side of (45), we obtain

$$\begin{aligned} y_t &= \frac{(\beta_0 + Bm_x)}{1-\alpha} + \alpha^t(y_0 - \frac{\beta_0 + Bm_x}{1-\alpha}) \\ &= y^* + \alpha^t(y_0 - y^*), \text{ when } -1 < \alpha < 1. \end{aligned} \tag{48}$$

In the stable case, the dynamic process is essentially correcting the initial discrepancy (disequilibrium) between the y_0 and steady-state y^*. Slow adjustment speed means that α is e.g. close to 1, and then most of the solution (e.g. the forecasted values) will be conditioned by the history of y, i.e. y_0 in this case.

$\alpha = 1$ in (44) is a special case of considerable interest, since it corresponds to no cointegration in the relevant case where x_t is a stationary time-series variable in first differences. In this non stationary case, the long-run relationship for y^* in (47) has no foundation in the dynamic model, the logical consequence is to replace (44) by

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t + \varepsilon_t \tag{49}$$

for forecasting purposes. Clearly, the initial value y_0 will now have full influence on the forecast for the level y_{t+j}, no matter how long the forecasting horizon is. Theoretical information on the other hand, has no influence.

Formal analysis of the stability properties of a larger macroeconometric model can be done, with the aid of the calculated roots of the final equations of the model. These roots

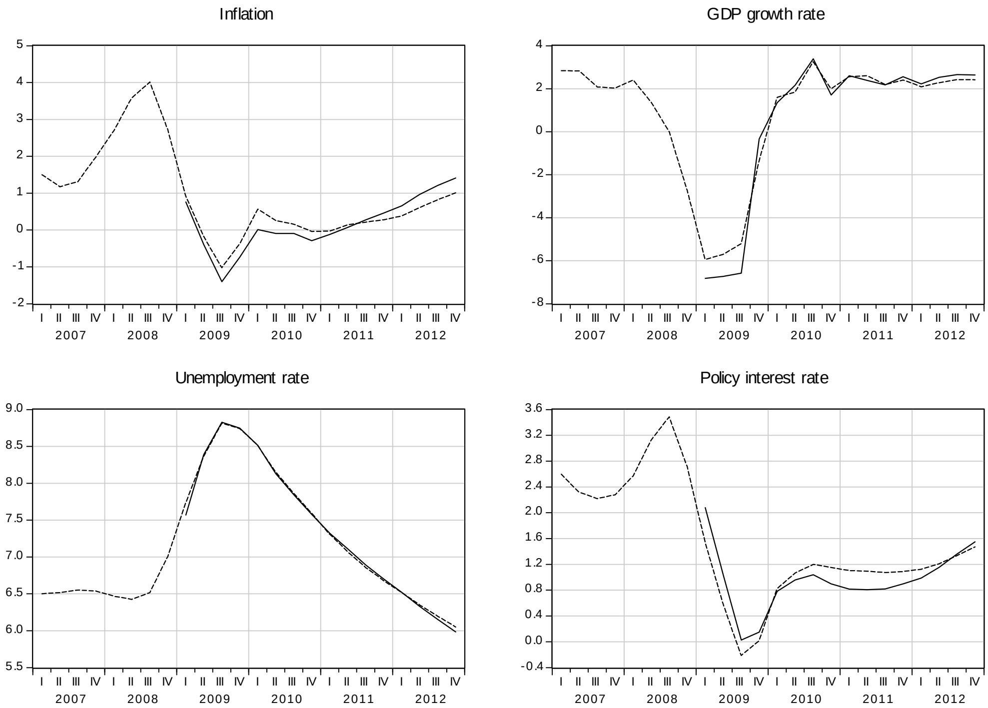

Figure 3: Assessing the importance of starting values for convergence by starting the simulations in 2007(1) and 2009(1) for inflation, output growth, unemployment rate, and the policy interest rate.

are the counterparts to α in the simple case above. However, such formal analysis goes beyond the scope of this documentation, and also well beyond what is needed to gain insight into the qualitative stability properties of MOSES. Graphs of dynamic simulations over a time horizon may be used to gain an impression of the speed of adjustments that shape the solution of the endogenous variables of the model. The horizon may be longer than the intended use of the model, but still short-enough to be of some practical interest.

Figure 3 shows dynamic simulations for four macroeconomic variables which are endogenous in MOSES. There are two simulations in each graph. One starts in 2007(1), the solid line, and the other starts in 2009(1). Because of the financial crisis in particular, one could expect the differences between these starting values to be quite large. This is not the case at all. The two solutions for inflation, the GDP growth rate, the unemployment rate, and the policy interest rate all converge relatively fast to about the same values in 2012q4. This is suggestive of stable steady-states, and quite high speed of adjustment. The solution for unemployment in particular is implying that the rate of unemployment in 2009 is above the steady-state equilibrium level (corresponding to u^* in Figure 2).

5.2 In-sample dynamic simulations

Figure 4 documents the dynamic simulation properties of MOSES for inflation, output growth, unemployment rate, and the policy interest rate.[7] Considering that the only exogenous variables are energy prices and unemployment programmes, the in-sample dynamic simulation performance is quite impressive. However, note that the simulations are conditional upon the 18 impulse dummies which represent outliers and possible structural breaks occurring over the period 1997-2009. This clearly help keep the simulations "on

[7] The 95 % prediction intervals are constructed by Monte Carlo simulation of the model.

track", so a similar performance cannot be expected for real time forecasts made before breaks have occurred.

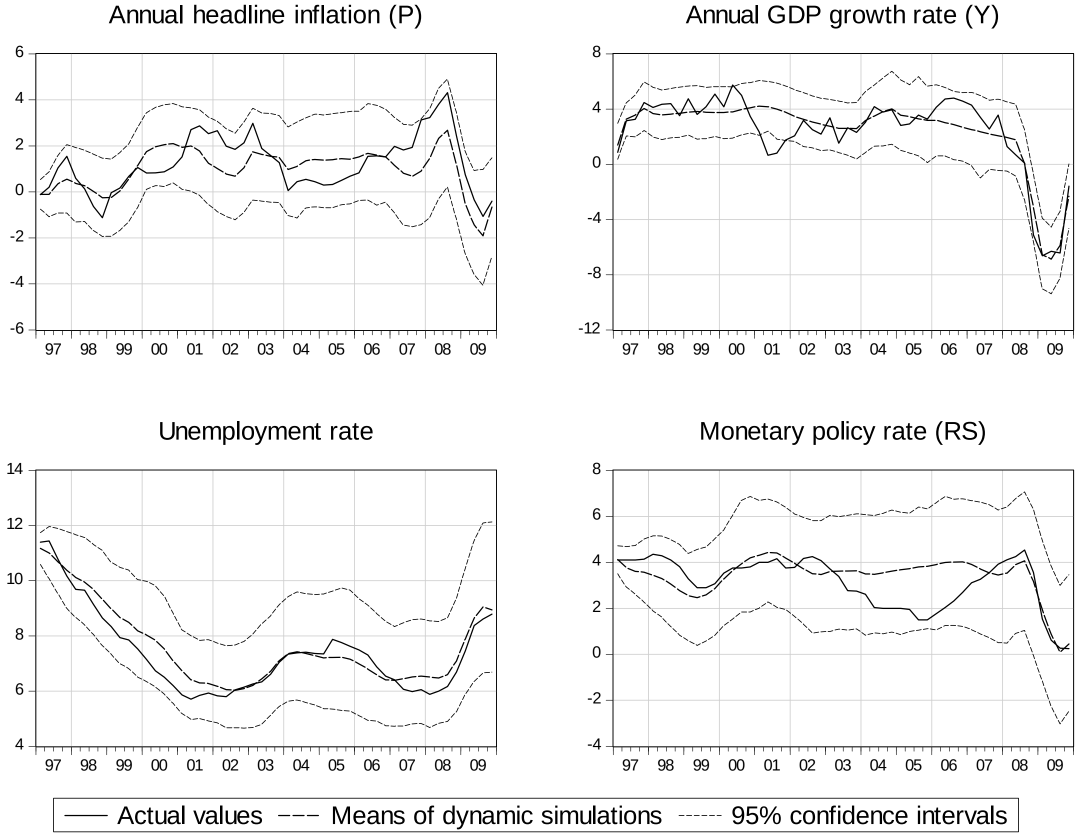

Figure 4: Dynamic simulations from 1997(1) until 2009(4) of annual inflation, the annual GDP growth rate, the unemployment rate, and the policy interest rate. The dotted bands are the 95% confidence intervals.

5.3 Effects of monetary policy

Figure 5 illustrates the effects of a negative monetary policy shock. A one period negative impulse of 100 basis points to the policy rate will on average increase inflation by a fifth of a percentage point at the maximum 6 quarters later, while the expected maximum response in output is 0.1 percentage points. The unemployment rate will respond even less and the effect is not significant.

The gradual increase in inflation after monetary policy shock seen here is often associated with backward-looking models. It should be noted therefore that also forward-looking models—with lead terms—will give the same qualitative response as long as the model has a solution which is stable from given initial conditions—excluding solutions with jumps in the inflation rate. Hence, it is the nature of the solution which is important, not whether equations of the model has a forward-looking terms or not. The speed of adjustment with respect to this monetary policy shock seems to be relatively fast in the model. For example, the graph shows that the interest rate returns to its initial level in the course of 10 periods.

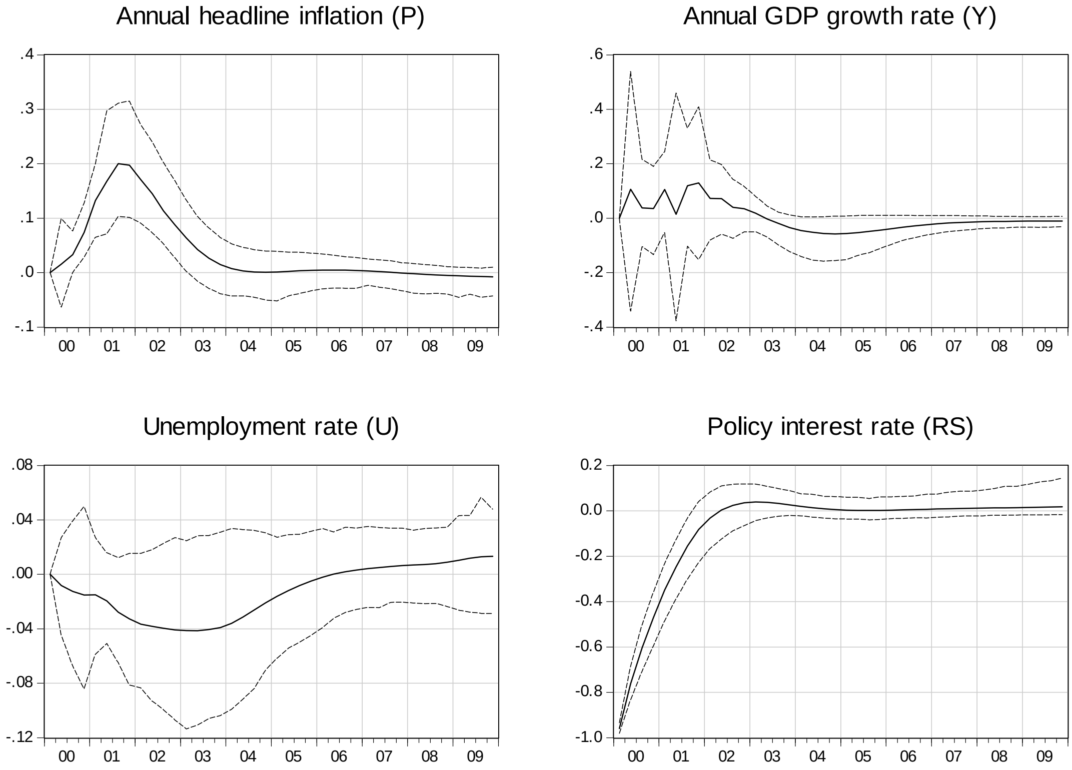

Figure 5: The effects of 100 basis points reduction in the interest rate (lower right) on inflation, output growth and unemployment rate.

5.4 A foreign shock

The previous shock illustrated the transmission mechanism of Swedish monetary policy. A second shock illustrates how the domestic variables react to a foreign shock made up of a drop in the growth rate among Sweden's trading partners (YF) and a permanent reduction the nominal USD price of oil ($SPOIL$), for example as a result of a financial crisis. Technically, we implement this experiment by decreasing foreign output (YF) for the four quarters in 2000, and by permanently reducing the oil price ($SPOIL$) and the energy price (PE) by 10%, starting in the first quarter of 2000.

The size of the shock to foreign GDP can be seen in the upper left panel of Figure 6, which shows that the annual growth rate falls by 1% in the first quarter and that largest deviation from the baseline is -4.6%, in the last quarter of 2000.

The upper middle panel of Figure 6 shows the response of the Swedish GDP growth rate to the joint shock. The reduction in the growth rate is smallerer than for foreign GDP, -3.8% versus -4.6% in 2000(4). As a reference, it is interesting to note that the largest negative growth rate in Sweden during the actual crisis of 2009 was 4.8%. The recovery in the domestic growth rate is quite forceful, and persistent.The same qualitative development was observed during the actual financial crisis. The right upper panel shows the response of the rate of unemployment, while the lower left and middle panels show that the responses of the real interest rate (a temporary reduction) and the real exchange rate (a temporay depreciation) are in part "responsible" for the strong recovery. Finally, the lower right panel shows that as result of the fall in foreign prices, there is a temporary reduction in the Swedish rate of inflation, which is however not very large in magnitude.

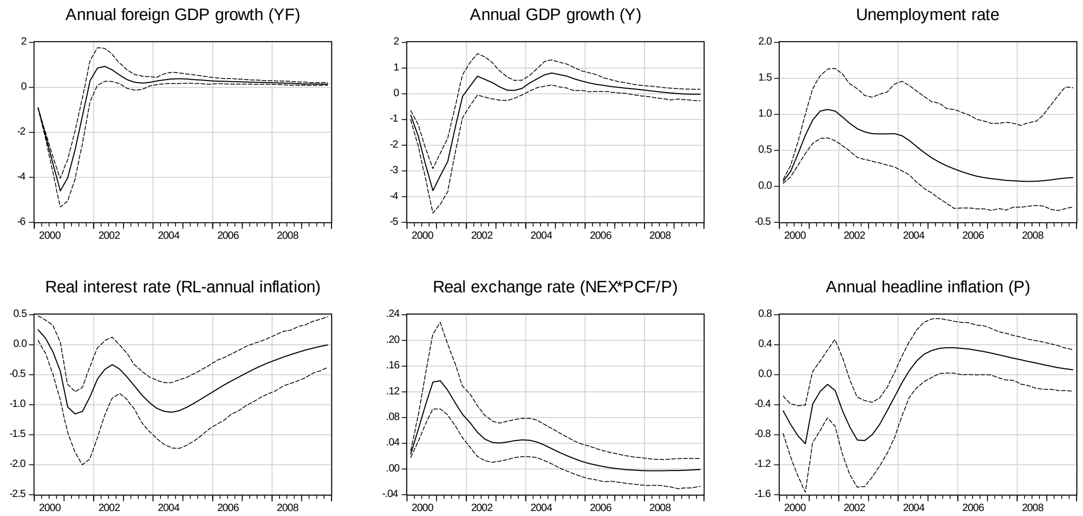

Figure 6: The effects of a four-quarter fall in world output (YF) and 10 per cent permanent fall in the world price of oil ($SPOIL$).

6 MOSES forecasts

In this section we report forecasts for the Swedish economy from MOSES. The only "technical" premise is that the model has been estimated on a relevant sample, in this case the sample that ends in 2009(4), with the results reported in Appendix A. In a realistic, practical, forecasting situation late in 2009, one particular concern would have be how to tackle non-modelled effects of the global financial and credit crisis, in particular the response of monetary policy. In this experiment none of these issues are taken into account, so the interest rate setting is assumed to follow inflation targeting as set out in (64).[8]

Having fixed the initial conditions to 2009(4), the solution of the model, and hence the forecast, since the model has a simple causal solution, only depends on the assumptions about the model's exogenous variables. As explained above there are four such variables: The degree of accommodation in labour market programmes ($AMUN$), the replacement rate in the unemployment insurance (RPR), energy prices in the consumer price index (PE), and the raw-oil price ($SPOIL$).

Figure 7 shows graphs of these four variables over the period 2007(1)-2011(2). For labour market programmes ($AMUN$) and the replacement rate (RPR) the levels in 2009(4) are simply extrapolated in the forecast period. For energy prices we assume moderate and even growth compared to what the recent history shows, and the oil price has a small positive growth rate. These assumptions are mainly illustrations and not optimal choices for model input.

Based on the above, the dynamic simulation of MOSES gives forecasts as shown in Figures 8-10. Figure 8 shows that domestic inflation is increasing again in the first period of the forecast period: We report two inflation measures, one for the 'core inflation' rate defined as the annual growth in the consumer price index net of interest rate payments (variable PFR in the model), and the other is the headline inflation, based on the ordinary consumer price index (P). We see that the core inflation is overpredicted, while headline inflation is overpredicted, although well within the 95% confidence interval. The rate of wage growth is in particular well forecasted. The second row of graphs shows the rate of nominal currency depreciation to the left, and then import price growth and foreign consumer price inflation. The graph for depreciation is perhaps the most interesting since

[8] The forecasts in this example are pure model forecasts—no adjustments are made.

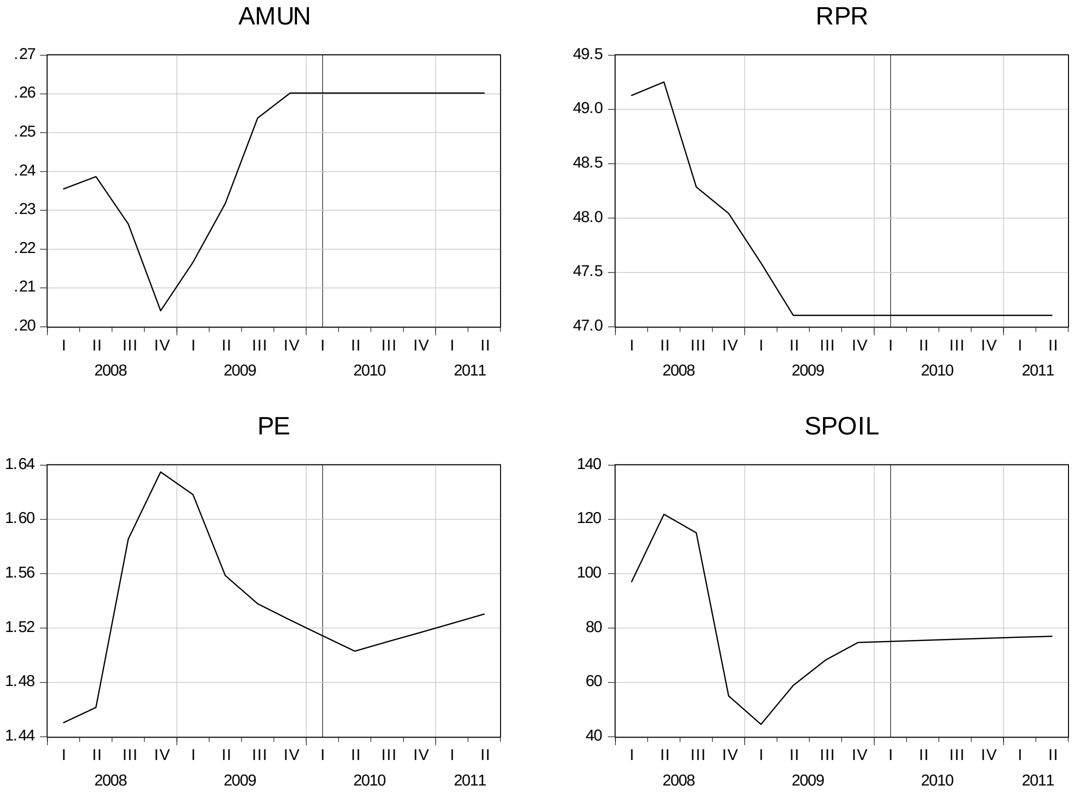

Figure 7: Paths for the exogenous variables in the forecasts: $AMUN$ is the labour market accommodation rate, RPR is the replacement rate, PE is the percentage change in the energy component in the consumer price index, $SPOIL$ is the price of oil per barrel in USD.

it shows that the model captures the turning point in the initial appreciation.

Figure 9 shows the forecasted evolution of Sweden on it's way out of the financial crisis, represented by six important real variables. The GDP growth is projected positive, but too low, and settles quickly around a growth rate of 3%. The graph of the unemployment reinforces the positive development of the macro economy, and captures the steady fall towards an equilibrium level below 5%.[9] The graph to the right in the first row of Figure 9 shows the productivity growth associated with this development, which is remarkably spot on and marked by a positive growth rate, settling around 2-3%.

In the left panel of the second row of Figure 9 the real exchange rate is appreciating towards an equilibrium with stronger terms of trade after 2011. As noted above, stability of this variable is key to overall stability of the nominal path defined by MOSES. The forecast path is consistent with the nominal development shown in Figure 8 above. The graph in the middle shows the wage-share, which is also a very important variable to check for stability. The speed of adjustment is a good deal slower for this variable, but that is not unreasonable, given the complexity of the economy, as borne out by the accuracy of the forecast. The last graph in this figure shows public expenditure as a share of GDP. As noted above, the level of public expenditure is an endogenous variable in MOSES. In accordance with the positive forecasts of GDP and the modelling of fiscal policy, the increase in relative public expenditure is reduced markedly through 2010, in line with the actual outcomes, towards it's long-run level of a quarter of GDP.

[9] Note that an equilibrium level of unemployment is an endogenous property of the full model, rather than an imposed value.

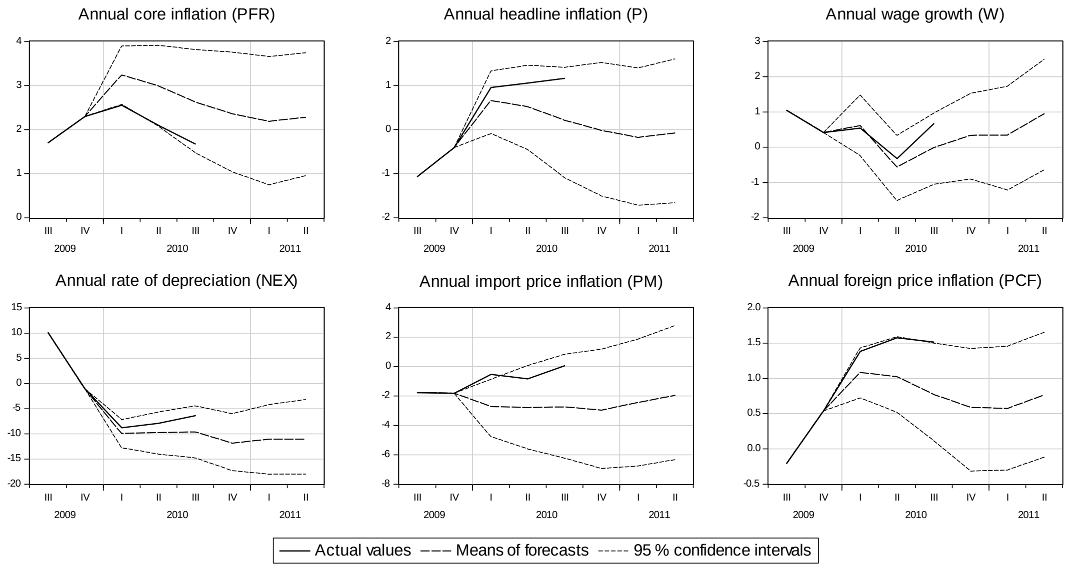

Figure 8: Forecast results for nominal variables for 2010(1)-2011(2) together with actual values for 2010(1)-2010(3).

Figure 10 shows forecasts for short and long interest rates. The most important variable here is the short interest rate (which is the Riksbank's policy rate). The outcomes here are outside the prediction intervals, which makes perfect sense, since monetary policy must try to mitigate the shock of the financial crisis. As demonstrated by Bårdsen et al. (2012), in case of a shock to target variables, forecasts of policy variables should miss if target variables are to be forecasted well—given the correct model. The second row of the graph shows forecasts for the yield on 10 year domestic government bonds, and for the foreign policy rate and the foreign bond rate.

The final question is how well MOSES is doing compared to other competing models, namely a DSGE-model and a BVAR.

7 Forecast comparisons

In this exercise, forecasts are generated over the period 2000(1) - 2009(4) for a forecast horizon of $h = 1, ..., 12$ periods ahead. This forecast horizon reflects the medium term that is relevant in a practical policy context. We analyze the forecast performance of a number of key[10] variables $x = \{y, pfr, RS\}$, where y is the log of GDP, pfr is the log of core consumer prices and RS is the policy interest rate, see the appendix for data definitions. For each iteration of the forecasting exercise, the initial conditions consists of the data realizations and the future paths of the exogenous variables are assumed to remain constant equal to their latest realizations. So, the final iteration for 2009(4) coincides with the one reported in the previous section regarding the initial conditions, but however with constant paths for the exogenous variables instead of those reported in Figure 7.

We compare the forecasting performance of MOSES with two other models that are employed in the policy process. These are the dynamic stochastic general equilibrium (DSGE) model RAMSES of Adolfson et al. (2008) and a vector autoregression model estimated with Bayesian methods (BVAR). The forecasting performance of these two models over the sample 1999(1)-2005(4) is documented in Adolfson et al. (2007), which

[10] Although not reported here, we analyzed in addition the forecasting performance for the nominal effective exchange rate (NEX) and the house price (ph, in logs).

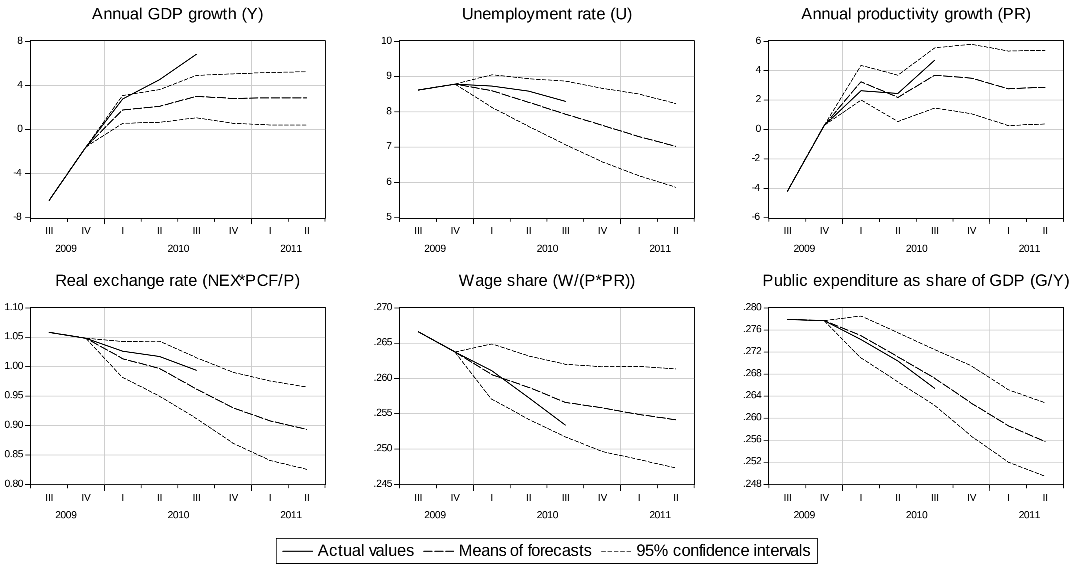

Figure 9: Forecast results for real variables for 2010(1)-2011(2) together with actual values for 2010(1)-2010(3).

considers moreover forecast combination, the role of judgement in forecasting and confronts the model forecasts with the official, published forecasts by Sveriges Riksbank[11].

Our forecast exercise is quasi and pseudo real-time. The exercise is quasi real-time in the sense that we abstract from data revisions and only consider the 2009(4) vintage, even though the revisions of Swedish National Account data are non-negligible, cf. Öller and Hansson (2004). The exercise is pseudo real-time in the sense that the same sample period is used for both model selection and forecast evaluation. This latter criticism is more relevant for the MOSES model than for the RAMSES and BVAR models. Concerning MOSES, the selected model and the estimated parameters as respresented in the Appendix are employed to generate the forecasts over the same sample. However, dummy variables are only active as part of the in-sample period and are never part of the forecast horizon.

Let the realisations of variable x for the sample $t = 1, ..., T$ be denoted as $\left(x_{1|T},...,x_{t|T},...x_{T|T}\right)$ and the T-dated forecasts as $\left(x_{T+1|T},...,x_{T+h|T}\right)$. So, the h-step ahead forecasts $x_{t|t-h}$ relate to the forecast for $x_{t|t}$ generated at period $(t-h)$. Using seasonal dummies S_j and the dummy for 2008(4), i_{08q4}, capturing the outbreak of the credit crisis, the forecast performance is analyzed by the following regression equation:

$$\Delta x_{t|t} = \gamma \Delta x_{t-h|t-h} + \alpha + \beta \Delta x_{t|t-h} + \textstyle\sum_{j=1}^{3} \delta_j S_j + \iota_1 i_{08q4} + \epsilon_t. \qquad (50)$$

Considering the simple regression equation $\Delta x_{t|t} = \alpha + \beta \Delta x_{t|t-h} + \epsilon_t$, then a good model forecast would imply the intercept $\alpha = 0$, the slope coefficient $\beta = 1$ and a high goodness-of-fit measure R^2 for every horizon h. An intercept different from zero implies biased forecasts and a slope different from one implies consistent over-/underpredicted deviations from the mean. Moreover note that the root mean squared error (RMSE) defined as $\sqrt{\frac{1}{T}\sum\left(\Delta x_{t|t} - x_{t|t-h}\right)^2}$ for horizon h corresponds with the standard deviation of ϵ_t in equation (50) in case $\beta = 1$ and the other parameters are equal to zero. So, the

[11] However, in the policy making context, the models MOSES, RAMSES and BVAR are being conditioned on the foreign sector as well. Note that the three models are small open economy models in the sense that there exists only a one-way causality from the foreign sector to the domestic variables. The three models are conditioned on the exogenised values for foreign GDP (YF), the foreign consumer price index (PF) and the foreign three month money market interest rate (RSF). Results of the forecasting exercise based on these exogenised variables are available upon request.

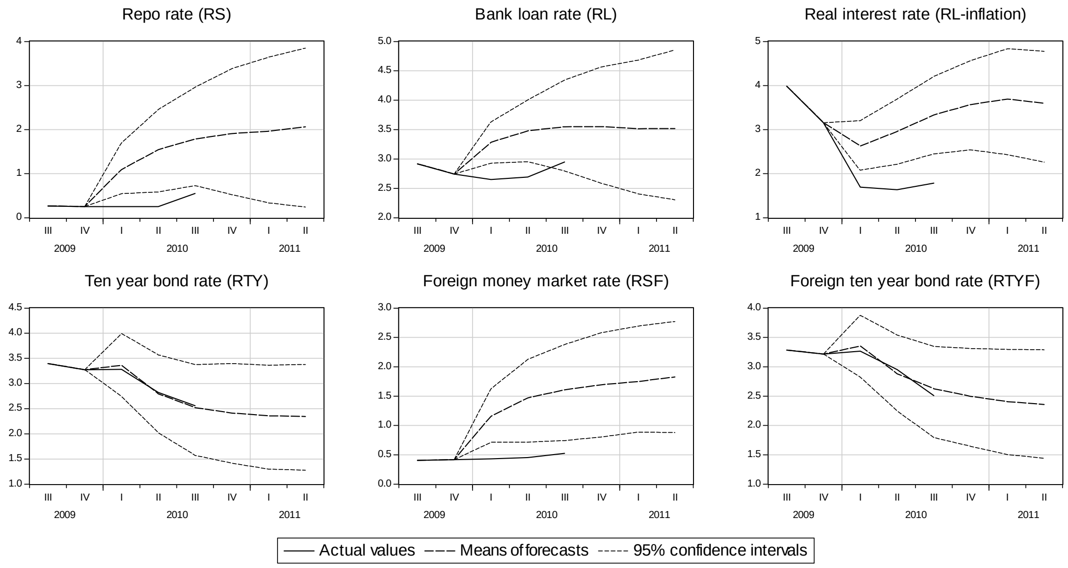

Figure 10: Forecast results for interest rates for 2010(1)-2011(2) together with actual values for 2010(1)-2010(3).

RMSE is only a good statistic in case the forecasts are unbiased and do not consistently over- or underpredict. Otherwise the goodness-of-fit statistic R^2 of equation (50) is more feasible. Considering the autoregressive augmented equation $\Delta x_{t|t} = \gamma \Delta x_{t-h|t-h} + \alpha + \beta \Delta x_{t|t-h} + \epsilon_t$, then a significantly estimated parameter $\widehat{\beta}$ indicates that the underlying model generating the forecasts $\Delta x_{t|t-h}$ possesses some forecasting power for the specific variable x, especially so in case $\widehat{\beta} > \widehat{\gamma}$.

Table 1 presents the autoregressive parameter γ, the intercept α and the slope β regarding the three different models RAMSES, MOSES and BVAR and the three target variables $x = \{y, pfr, RS\}$ being GDP, inflation and the policy interest rate. The results of the slope parameter shows that MOSES performs very well for GDP and the interest rate for all forecast horizons, while RAMSES performs quite well for the interest rate and BVAR performs quite well for GDP. None of the models show good performance for CPI. Moreover, the R^2 of the different models for CPI are relatively low, which indicates low forecastablity for this variable. The outperformance of MOSES should be interpreted with care though as the data and sample used for model selection is identical to the data and sample used for evaluating the forecast performance. Note that the BVAR shows significant forecast performance for GDP for a horizon up to 4 quarters ahead. The result that economic models show forecastability for longer horizons contrasts for instance with the results of Edge and Gürkaynak (2010). They analyse the forecasting performance of a BVAR and a DSGE model together with published forecasts for American data over the sample 1992-2004. Based on the forecast evaluation regression (50) with $\gamma = \delta_j = \iota_1 = 0$ and employing real-time data, they find that GDP and CPI are unforecastable beyond a forecast horizon of one quarter ahead.

8 Conclusions

We have documented MOSES, which is an aggregate econometric model for Sweden. The model has been constructed with the requirement of short-term forecasting over the policy horizon in mind. The model is based on a coherent econometric modelling strategy combined with the use of relevant economic theories for the different markets covered by

Table 1: Forecast performance for GDP

	Quarters ahead					
Forecast	**1**	**2**	**3**	**4**	**8**	**12**
RAMSES						
Autoregr	0.42	0.23	0.35	-0.13	0.24	-0.60
	(2.72)	(1.77)	(1.68)	(-0.62)	(0.98)	(-2.89)
Intercept	0.37	0.58	0.85	1.13	-0.67	-0.26
	(1.90)	(2.23)	(2.18)	(1.94)	(-0.57)	(-0.27)
Slope	-0.25	-0.44	-1.30	-0.83	1.63	1.63
	(-0.89)	(-0.89)	(-1.55)	(-0.78)	(1.02)	(1.32)
R^2	0.80	0.77	0.77	0.76	0.78	0.88
MOSES						
Autoregr	-0.04	0.00	-0.08	-0.23	0.19	-0.39
	(-0.33)	(0.01)	(-0.55)	(-1.57)	(1.15)	(-2.47)
Intercept	0.12	0.16	0.21	0.39	0.12	0.52
	(0.69)	(1.06)	(1.09)	(2.11)	(0.55)	(2.52)
Slope	0.67	0.58	0.58	0.56	0.54	0.45
	(3.56)	(5.80)	(5.14)	(5.51)	(5.18)	(4.56)
R^2	0.86	0.89	0.87	0.88	0.89	0.94
BVAR						
Autoregr	0.20	0.10	0.16	-0.20	0.17	-0.70
	(2.10)	(1.04)	(0.86)	(-0.98)	(0.73)	(-3.57)
Intercept	-0.39	-0.88	-1.92	-1.62	-1.52	3.78
	(-0.95)	(-1.19)	(-1.96)	(-1.56)	(-0.94)	(1.75)
Slope	0.98	1.63	2.93	3.07	2.88	-4.17
	(1.98)	(1.86)	(2.42)	(2.31)	(1.27)	(-1.30)
R^2	0.82	0.79	0.80	0.80	0.79	0.88

Parameter estimates and t-values of forecast evaluation regression (50)

the model. The degree of endogeneity of MOSES is high, very few variables are set by the model user, and in this respect MOSES is more comparable to structural VARs and DSGE-models than to traditional sector-by-sector macroeconometric models. In terms of econometric methodology, MOSES is perhaps closer to the econometric tradition of quantitative macroeconomic modelling.

The majority of the equations of MOSES have been estimated on a shorter sample that covers the era of operational inflation targeting, i.e. from 1995.[12] The choice of a relatively short sample period increases the relevance of the estimation results for the present monetary policy regime. In terms of precision of the estimates, and robustness of the specified model structure to future developments, the relatively few number of observations is of course not ideal. However, since the economy is in any case constantly evolving, only time can show if we have succeeded in establishing functional relationships for the Swedish economy that have some degree of permanence and therefore contain structural content. Experience from an aggregate model of Norway gives reason for optimism, given the right approach to model maintenance which involve quality control, adaptation of the model specification in the light of new data as they come along, see Bårdsen and Nymoen (2009a).

[12] http://www.riksbank.com/upload/Dokument/rb_10years.pdf.

Forecast performance for CPI

	Quarters ahead					
Forecast	**1**	**2**	**3**	**4**	**8**	**12**
RAMSES						
Autoregr	-0.02	-0.02	0.04	-0.05	0.08	-0.16
	(-0.30)	(-0.31)	(0.34)	(-0.38)	(0.59)	(-0.97)
Intercept	0.40	0.37	0.36	0.46	0.25	0.24
	(2.43)	(2.48)	(1.99)	(2.56)	(1.42)	(0.85)
Slope	0.30	0.52	0.44	0.37	1.50	2.30
	(1.25)	(2.00)	(1.42)	(0.99)	(2.63)	(1.38)
R^2	0.13	0.19	0.13	0.11	0.32	0.20
MOSES						
Autoregr	-0.00	-0.03	0.06	-0.07	0.05	-0.13
	(-0.05)	(-0.39)	(0.40)	(-0.49)	(0.33)	(-0.77)
Intercept	0.29	0.43	0.34	0.37	0.37	0.49
	(1.25)	(1.99)	(1.31)	(1.75)	(1.91)	(2.26)
Slope	0.40	0.16	0.23	0.33	0.26	0.16
	(1.16)	(0.47)	(0.66)	(1.15)	(0.89)	(0.48)
R^2	0.13	0.09	0.08	0.12	0.14	0.13
BVAR						
Autoregr	0.01	-0.01	0.07	-0.04	0.15	-0.13
	(0.14)	(-0.09)	(0.51)	(-0.25)	(0.96)	(-0.76)
Intercept	0.06	0.11	-0.00	0.12	-0.63	0.96
	(0.19)	(0.33)	(-0.00)	(0.26)	(-0.83)	(0.77)
Slope	1.03	0.90	1.10	0.92	2.41	-0.99
	(1.66)	(1.25)	(1.26)	(0.94)	(1.45)	(-0.36)
R^2	0.16	0.13	0.12	0.11	0.19	0.13

Parameter estimates and t-values of forecast evaluation regression (50)

References

Adolfson, M., Andersson, M., Lindé, J., Villani, M., Vredin, A., 2007. Modern forecasting models in action: Improving macroeconomic analyses at central banks. International Journal of Central Banking 3 (4), 111–144.

Adolfson, M., Laséen, S., Lindé, J., Villani, M., 2008. Evaluating an estimated new keynesian small open economy model. Journal of Economic Dynamics and Control 32 (8), 2690–2721.

Akram, Q. F., Nymoen, R., 2009. Model selection for monetary policy analysis—how important is empirical validity? Oxford Bulletin of Economics and Statistics 71, 35—68.

Bårdsen, G., 1989. Estimation of long run coefficients in error correction models. Oxford Bulletin of Economics and Statistics 51, 345–350.

Bårdsen, G., Eitrheim, Ø., Jansen, E. S., Nymoen, R., 2005. The Econometrics of Macroeconomic Modelling. Oxford University Press, Oxford.

Bårdsen, G., Hurn, S., Lindsay, K., 2004. Linearizations and equilibrium correction models.

Forecast performance for the interest rate

	Quarters ahead					
Forecast	**1**	**2**	**3**	**4**	**8**	**12**
RAMSES						
Autoregr	0.28	0.10	0.30	0.29	0.20	-0.19
	(4.50)	(1.28)	(1.93)	(1.70)	(1.04)	(-0.92)
Intercept	-0.16	0.00	-0.19	-0.12	-0.08	-0.03
	(-1.27)	(0.01)	(-0.98)	(-0.56)	(-0.37)	(-0.10)
Slope	0.24	0.82	0.93	1.05	2.57	4.39
	(1.31)	(2.42)	(1.95)	(1.54)	(1.73)	(2.05)
R^2	0.61	0.44	0.39	0.31	0.31	0.33
MOSES						
Autoregr	0.22	0.08	0.10	0.11	0.16	0.13
	(3.21)	(1.28)	(0.86)	(1.17)	(1.44)	(0.96)
Intercept	-0.15	-0.05	-0.00	-0.02	0.19	0.30
	(-1.25)	(-0.39)	(-0.00)	(-0.19)	(1.38)	(1.86)
Slope	0.54	1.10	1.38	1.51	1.90	1.93
	(2.21)	(4.33)	(5.69)	(8.25)	(7.60)	(6.51)
R^2	0.64	0.59	0.68	0.79	0.78	0.75
BVAR						
Autoregr	0.32	0.21	0.37	0.29	0.30	-0.03
	(5.82)	(2.90)	(2.41)	(1.77)	(1.42)	(-0.13)
Intercept	-0.22	-0.13	-0.25	-0.18	-0.09	0.19
	(-1.74)	(-0.83)	(-1.22)	(-0.92)	(-0.37)	(0.68)
Slope	0.17	0.36	0.32	0.49	-0.04	-0.74
	(0.89)	(1.55)	(1.32)	(1.96)	(-0.11)	(-1.52)
R^2	0.60	0.37	0.34	0.35	0.22	0.27

Parameter estimates and t-values of forecast evaluation regression (50)

Studies in Nonlinear Dynamics and Econometrics 8 (5).
URL http://www.bepress.com/snde/vol8/iss4/art5

Bårdsen, G., Jansen, E. S., Nymoen, R., 2003. Econometric inflation targeting. Econometrics Journal 6 (2), 429–460.

Bårdsen, G., Kolsrud, D., Nymoen, R., 2012. Forecast robustness in macroeconometric models, working Paper.

Bårdsen, G., Nymoen, R., 2003. Testing steady-state implications for the NAIRU. The Review of Economics and Statistics 85 (4), 1070–75.

Bårdsen, G., Nymoen, R., 2009a. Macroeconometric modelling for policy. In: Patterson, K., Mills, T. (Eds.), The Palgrave Handbook of Econometrics. Vol. 2. Palgrave.

Bårdsen, G., Nymoen, R., 2009b. U.S. natural rate dynamics reconsidered. In: Castle, J. L., shephard, N. (Eds.), The Methodology and Practise of Econometrics. Oxford University Press.

Blanchard, O. J., Kahn, C. M., 1980. The solution of linear difference models under rational expectations. Econometrica 48 (5), 1305–1312.

Blanchflower, D. G., Oswald, A. J., 1994. The Wage Curve. The MIT Press, Cambridge, Massachusetts.

Claeys, P., 2008. Rules, and their effects on fiscal policy in sweden. Swedish Economic Policy Review 15, 7–47.

Doornik, J. A., 2009. Autometrics. In: Castle, J. L., Shephard, N. (Eds.), The Methodology and Practise of Econometrics. Oxford University Press, Ch. 4, pp. 88–121.

Edge, R. M., Gürkaynak, R., 2010. How useful are estimated DSGE model forecasts for central bankers? Brookings Papers on Economic Activity, 209–244Fall.

Fernandez-Villaverde, J., Rubio-Ramirez, J., Sargent, T., Watson, M., 2007. ABCs (and Ds) of understanding VARs. American Economic Review 97, 1021–1026.

Forslund, A., Gottfries, N., Westermark, A., March 2008. Prices, productivity and wage bargaining in open economies. Scandinavian Journal of Economics 110 (1), 169–195.

Garratt, A., Lee, K., Pesaran, M. H., Shin, Y., 2006. Global and National Macroeconometric Modelling: A Long-Run Structural Approach. Oxford University Press.

Granger, C. W., 1992. Fellow's opinion: Evaluating economic theory. Journal of Econometrics 51, 3–5.

Hendry, D. F., 1995. Dynamic Econometrics. Oxford University Press, Oxford.

Hendry, D. F., Krolzig, H.-M., 1999. Improving on 'data mining reconsidered' by K. D. hoover and S. J. perez. Econometrics Journal 2, 202–219.

Hoover, K. D., Perez, S. J., 1999. Data mining reconsidered: Encompassing and the general-to-specific approach to specification search. Econometrics Journal 2, 167–191.

Johansen, S., 1995. Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press, Oxford.

Johansen, S., 2006. Cointegration: an overview. In: Mills, T. C., Patterson, K. (Eds.), Palgrave Handbook of Econometrics. Vol. 1 of Econometric Theory. Palgrave-MacMillan.

Juselius, K., 2007. The Cointegrated VAR Model: Methodology and Applications. Oxford University Press.

Kolsrud, D., Nymoen, R., 1998. Unemployment and the open economy wage-price spiral. Journal of Economic Studies 25, 450–467.

Layard, R., Nickell, S., Jackman, R., 2005. Unemployment, 2nd Edition. Oxford University Press, Oxford, first published 1991.

Lütkepohl, H., 2006. Vector autoregressive models. In: Mills, T. C., Patterson, K. (Eds.), Econometric Theory. Vol. 1 of Palgrave Handbook of Econometrics. Palgrave MacMillan, pp. 287–325.

Nymoen, R., Rødseth, A., 2003. Explaing unemployment: some lessons from nordic wage formation. Labour Economics 10, 1–29.

Öller, L.-E., Hansson, K.-G., 2004. Revision of national accounts. Journal of Business Cycle Measurement and Analysis 3, 363–386.

Ravenna, F., 2007. Vector autoregressions and reduced form representations of DSGE models. Journal of Monetary Economics 54, 2048–2064.

Sørensen, P., Whitta-Jacobsen, H. J., 2010. Introducing Advanced Macroeconomics: Growth and Business Cycles, 2nd Edition. McGraw-Hill Education.

Spanos, A., 2008. Suffiency and ancillarity revisited: testing the validity of a statistical model. In: Castle, J. L., Shephard, N. (Eds.), The Methodology and Practice of Econometrics. Oxford Univeristy Press, Oxford.

Watson, M. W., 1994. Vector autoregressions and cointegration. Vol. 4 of Handbook of Econometrics. Elsevier Science, Amsterdam, Ch. 47, pp. 2843–2915.

A Appendix: Econometric results

The sample period covers the period after Sweden's change from a fixed to a floating exchange rate regime in November 1992. The majority of the equations are estimated on shorter sample periods, beginning with the period of explicit inflation targeting. The resulting model, corresponding to Figure 1, is presented in Tables 2 - 4. The first term on right hand side of each equation is an equilibrium correction coefficient, multiplied by the associated lagged deviation from steady-state (inside brackets). The cointegrating relationships in the sub-models have been estimated by means of the Johansen(1995) procedure, while the single-equation relationships have been estimated using the method of Bårdsen(1989).[13] To save space, seasonal dummies are not reported.

Starting with the exchange rate channel of monetary policy, the main determinant of movements in the nominal exchange rate is interest differential $RS - RSF$ in (51). Exchange rate movements then affects import prices through a pass-through process in (52).

Import price inflation provides the link to the labour market and the price-wage inflation model (53 and 54), where prices are set as a mark-up on labour- and intermediate costs while the wage share is negatively affected by the unemployment rate.

Productivity modelled in (55) represents aggregate supply effects and, in accordance with efficiency wage theories, is a function of the real wage and the unemployment rate. The equilibrium unemployment rate defined by (56) is a function of labour market policy in the form of training programmes and the replacement ratio, while the dynamics are mainly a function of aggregate demand effects.

The aggregate demand in (57) is affected by fiscal policy through public demand G, but also by foreign demand YF and private demand through households demand for real credit CRN/P. The credit channel provides a link for monetary policy through the effects of the bank loan rate RL on households aggregate demand for credit modelled in (58), while public expenditure long-run budget consistency is captured through modelling public demand as a function of aggregate demand.

Monetary policy is modelled as a standard Taylor-rule reaction function with interest rate smoothing in (64), except that we use output growth rather than the unobserved output gap. The inflation target is in terms of inflation corrected for interest rate effects. In addition to inflation and output growth, the policy rate also reacts to the foreign interest rate. Finally, the transmission mechanisms of monetary policy from the policy rate to the bank lending rate and bond rate are modelled as a system in (62)-(63) again taking into account the openness of the Swedish economy.

[13] The parameters of the long-run relationships are reported without standard errors, which are available upon request, in the interest of readability.

Table 2: The equations in MOSES. Standard errors are reported in parentheses below the coefficients. See appendix B for information about the statistics reported below each equation

The exchange rate

$$\Delta nex_t = -\underset{(0.037)}{0.25}\left[(nex + pcf - p)_{t-1} + 0.07\,(RS_{t-1} - RSF_{t-2}) + 0.19u_{t-2} + 0.68yf_{t-2}\right] \tag{51}$$
$$+\underset{(0.008)}{0.05}\,\Delta RSF_{t-1} + \underset{(0.074)}{0.22}\,\Delta u_{t-1} - \underset{(0.280)}{2.36}\,\Delta_2 yf_t + \underset{(0.134)}{0.92}$$

Import prices

$$\Delta pm_t = -\underset{(0.041)}{0.10}\left[(pm - nex - ppi) - 0.6\,(p - nex - pf)\right]_{t-1} + \underset{(0.098)}{0.43}\,\Delta pm_{t-4} \tag{52}$$
$$+\underset{(0.048)}{0.39}\,\Delta nex_t - \underset{(0.049)}{0.18}\,\Delta nex_{t-4} - \underset{(0.094)}{0.32}\,\Delta ppi_{t-2} + \underset{(0.346)}{2.28}\,\Delta_4\Delta pcf_t + \underset{(0.109)}{0.17}\,\Delta y_t$$

Prices and wages

$$\Delta p_t = -\underset{(0.015)}{0.08}\left[p_{t-2} - 0.5\,(w - pr)_{t-1} - 0.5pm_{t-1}\right] + \underset{(0.060)}{0.10}\,\Delta\,(w - pr)_t \tag{53}$$
$$+\underset{(0.008)}{0.02}\,\Delta pe_t + \underset{(0.066)}{0.16}\,\Delta y_t + \underset{(0.170)}{1.08}\,\Delta pcf_t + \underset{(0.010)}{0.05}$$

$$\Delta w_t = -\underset{(0.023)}{0.18}\,(w_{t-3} - p_{t-1} - .6pr_{t-3} + 0.2u_{t-2}) - \underset{(0.144)}{0.70}\,\Delta_2 w_{t-1} - \underset{(0.009)}{0.06} \tag{54}$$

Productivity

$$\Delta pr_t = -\underset{(0.021)}{0.08}\left[pr_{t-5} - 0.86(w_{t-3} - p_{t-1}) - 0.06u_{t-2}\right] + \underset{(0.030)}{0.10}\,\Delta_3\,(w - p)_t \tag{55}$$
$$-\underset{(0.080)}{0.24}\,\Delta pr_{t-4} + \underset{(0.009)}{0.01}\,\Delta u_{t-1} - \underset{(0.004)}{0.01}\,\left[I92(4) + I96(2)\right]_t$$
$$-\underset{(0.006)}{0.04}\,I08(4)_t + \underset{(0.027)}{0.1}$$

Table 3: The equations in MOSES, continued

The rate of unemployment

$$\Delta u_t = -\underset{(0.016)}{0.02}\ u_{t-2} - \underset{(0.134)}{0.39}\ amun_{t-1} + \underset{(0.108)}{0.22}\ \Delta u_{t-1} - \underset{(0.200)}{0.68}\ \Delta amun_t \quad (56)$$

$$-\underset{(0.205)}{1.12}\ \Delta_3 y_t + \underset{(0.001)}{0.003}\ rpr_t - \underset{(0.025)}{0.04}\ I99(4)_t + \underset{(0.033)}{0.004}$$

GDP-output

$$\Delta y_t = -\underset{(0.054)}{0.15}\ (y - yf)_{t-1} + \Delta\left[\left(\frac{G}{Y}\right)_{t-1} g_t\right] - \underset{(0.111)}{0.34}\ \Delta y_{t-1} - \underset{(0.001)}{0.001}\ (RL - \pi)_{t-4} \quad (57)$$

$$-\underset{(0.111)}{0.34}\ \Delta y_{t-1} + \underset{(0.381)}{3.67}\ x\_s_t \Delta yf_t + \underset{(0.458)}{0.79}\ x\_s_{t-2} \Delta yf_{t-2} + \underset{(0.469)}{1.29}$$

Credit, house prices and housing stock

$$\Delta(crn - p)_t = -\underset{(0.015)}{0.09}\ \left\{(crn - p)_{t-1} - 0.27 y_{t-1} - 0.75\left[(ph - p)_{t-3} + hs_{t-1}\right] + .04 RL_{t-1}\right\} \quad (58)$$

$$+\underset{(0.103)}{0.23}\ \Delta(ph - p)_t - \underset{(0.004)}{0.01}\ \Delta RL_t + \underset{(-)}{0.079}\ I01(1)_t + \underset{(0.002)}{0.003}$$

$$\Delta(ph - p)_t = -\underset{(0.057)}{0.32}\ \left[(ph - p)_{t-2} - 0.85(crn - p)_{t-1} - 0.4(w + y - pr - p)_{t-1} + 0.7 hs_{t-3}\right] \quad (59)$$

$$+\underset{(0.153)}{0.32}\ \Delta(crn - p)_t + \underset{(0.180)}{0.51}\ \Delta(w + y - pr - p)_t - \underset{(0.032)}{0.14}\ \Delta u_t$$

$$-\underset{(-)}{0.04}\ I01(2)_t - \underset{(0.384)}{2.15}$$

$$\Delta hs_t = -\underset{(0.096)}{0.08}\ \left[hs_{t-3} - 0.15(crn - p)_{t-1}\right] - \underset{(0.105)}{0.36}\ \Delta hs_{t-1} - \underset{(0.110)}{0.46}\ \Delta hs_{t-2} \quad (60)$$

$$-\underset{(-)}{0.03}\ I96(1)_t + \underset{(1.190)}{1.01}$$

Table 4: The equations in MOSES, continued

Fiscal policy

$$\Delta g_t = -\underset{(0.047)}{0.34}\ (g_{t-4} - 0.25 y_{t-5}) - \underset{(0.051)}{0.11}\ \Delta_2 g_{t-1} - \underset{(0.051)}{0.18}\ \Delta y_{t-4} + \underset{(0.423)}{3.02} \qquad (61)$$

Interest rates

$$\Delta RTY_t = -\underset{(0.061)}{0.16}\ (RTY - 0.3RS - 0.85RTYF)_{t-1} + \underset{(0.06)}{1.14}\ \Delta RTYF_t \qquad (62)$$

$$\Delta RL_t = -\underset{(0.036)}{0.11}\ (RL - .7RTY - .7RS)_{t-1} + \underset{(0.045)}{0.66}\ \Delta RS_t \qquad (63)$$

$$+ \underset{(0.064)}{0.15}\ \Delta RTY_t - \underset{(-)}{0.51}\ I07(4)_t$$

Policy interest rate

$$\Delta RS_t = -\underset{(0.023)}{0.17}\ \left[RS_{t-1} - RSF_{t-1} - 1.4\,(\pi_{FRt} - 2) - 0.2\dot{Y}_t\right] \qquad (64)$$

$$+ \underset{(0.071)}{0.75}\ \Delta RSF_t,$$

where $\pi_{FRt} \equiv 100\Delta_4 PFR_{,t}/PFR_{,t-4}$ and $\dot{Y}_t \equiv 100\Delta_4 Y_t/Y_{t-4}$.

Inflation corrected for interest rates

$$(\pi_{FR} - \pi)_t = \underset{(0.036)}{1.0}\ (\pi_{FR} - \pi)_{t-1} + \underset{(0.131)}{0.54}\ \Delta\,(RL - RS)_t \qquad (65)$$

$$+ \underset{(0.210)}{1.38}\ I09(1)_t + \underset{(0.201)}{0.60}\ I09(2)_t + \underset{(0.030)}{0.02}$$

Table 5: The equations in MOSES—foreign block

Foreign producer prices

$$\Delta ppi_t = -\underset{(0.016)}{0.05}\ (ppi - 0.2spoil)_{t-1} + \underset{(0.079)}{0.22}\ \Delta ppi_{t-1} + \underset{(0.005)}{0.04}\ \Delta spoil_t \tag{66}$$

$$+ \underset{(0.005)}{0.02}\ I08(2)_t - \underset{(0.006)}{0.03}\ I08(4)_t - \underset{(0.006)}{0.014}\ I09(1)_t - \underset{(0.010)}{0.03}$$

Foreign consumer prices

$$\Delta pcf = -\underset{(0.004)}{0.01}\ (pcf - ppi)_{t-1} + \underset{(0.064)}{0.08}\ \Delta pcf_{t-1} + \underset{(0.060)}{0.2}\ \Delta pcf_{t-3} + \underset{(0.072)}{0.34}\ \Delta pcf_{t-4} \tag{67}$$

$$+ \underset{(0.016)}{0.22}\ \Delta ppi_t - \underset{(0.021)}{0.10}\ \Delta ppi_{t-4} + \underset{(0.009)}{0.04}\ 0.01\dot{YF}_{t-4},$$

where $\dot{YF}_t \equiv 100\Delta_4 YF_t / YF_{t-4}$.

Foreign aggregate demand

$$\Delta yf_t = -\underset{(0.0049)}{0.014}\ \left[yf_{t-3} - .08\,(RSF - \pi_F)_{t-2}\right] + \underset{(0.074)}{0.33}\ \Delta yf_{t-1} \tag{68}$$

$$- \underset{(0.003)}{0.01}\ I08(3)_t - \underset{(0.003)}{0.02}\ I08(4)_t - \underset{(0.003)}{0.02}\ I09(1)_t + \underset{(0.023)}{0.08}\ ,$$

where $\pi_{Ft} \equiv 100\Delta_4 PCF_t / PCF_{t-4}$.

Foreign policy rate

$$\Delta RSF_t = -\underset{(0.041)}{0.19}\ \left[RSF - 3.7 - (\pi_{FT} - 2) - 0.5\left(\dot{YF} - 3\right)\right]_{t-1} \tag{69}$$

$$+ \underset{(0.085)}{0.31}\ \Delta\pi_{Ft} + \underset{(0.055)}{0.15}\ \Delta\dot{YF}_t$$

Foreign bond rate

$$\Delta RTYF_t = -\underset{(0.022)}{0.09}\ (RTYF_{t-1} - RSF_{t-2}) + \underset{(0.095)}{0.51}\ \Delta^2 RSF_t \tag{70}$$

B Appendix: Data definitions

The model employs mainly seasonally adjusted data, and exceptions from this are noted in the list below. Unless another source is given, all data are taken from the MOSES database provided by Riksbanken. The database is the same as used for other models who currently is used in the forecast process, RAMSES II and BVAR.

The model is developed and estimated with *Oxmetrics 6* (www.oxmetrics.net) and then re-estimated and simulated with *Eviews 7* (www.eviews.com).

$AMUN$ Accomodative stance (with respect to unemployment). [MOSES database reference: (SYSS_SA+UTB_SA)/antal arbetslösa]

CRN Household debt current prices. [MOSES database reference: Hushållens totala finansiella skulder, löpande pris, SESKULDVQ]

G Government sector consumption expenditure fixed prices. [MOSES database reference: Offentlig konsumtions volym, SEGCSACAQ]

NEX Nominal effective exchange rate, TCW weighted nominal value of the Swedish krone (SEK).[MOSES database reference: Nominell, SEK/TCW, SETCWQ]

P Consumer price index.[MOSES database reference: KPI, säsongrensad, SECPISAQ]

PFR Consumer price index at constant interest rate.[MOSES database reference: KPIF, säsongrensad, SECPIFSAQ]

PE Energy price index, component of consumer price index [Energipriser i KPI, SEENCPIM].

PF Foreign consumer price index. [MOSES database reference: KPI, TCW-vägd, säsongrensad, TCWCPISAQ]

PH House price index. [MOSES database reference: Sweden, House Prices, Owner-occupied one- and two-dwelling buildings, whole country, Index, SEK, 1981=100]

PPI "World" producer price index, manufacturing. [MOSES database reference: Global PPI, manufacturing, TCW-vägd, index 2000=100, TCWPPIQ].

PM Import price index. [MOSES database reference: Importpris, SEMPQ. Not seasonally adjusted]

PR Average labour productivity [MOSES database reference: Arbetsproduktivitet i hela ekonomin, säsongrensad, GDP/HOURS , SEYSACOQ/SEHOURSSAQ].

RPR Replacement ratio, percentage. [MOSES database reference: Ersättningsgrad vid arbetslöshet, SEEAFSAQ].

RSF Foreign "repo" rate. [MOSES database reference: Reporänta, TCW-vägd,TCWREPOQ].

RS "Repo" rate. [MOSES database reference:Reporänta, SEREPOQ].

RL Bank loan rate. [MOSES database reference: Sweden, Personal Lending Rates, Banks, Households incl. NPISH, All loans, SEK].

RTY 10 year domestic interest rate. [MOSES database reference: 10-årsränta, SER10YQ].

$RTYF$ 10 year foreign interest rate. [MOSES database reference: 10-årsränta utland, TCWR10YQ].

$SPOIL$ Oil price index. [MOSES database reference: Oljepris, Brent, WDPOQ, USD]

Y GDP. [MOSES database reference:BNP volym, säsongrensad, SEYSACAQ].

YF Foreign GDP. [MOSES database reference:BNP volym, TCW-vägd, säsongrensad, TCWYSAQ]

U Unemployment percent of labour force. [MOSES database reference: Andel arbetslösa, ILO-definition, säsongrensad, SEURILOSAQ]

W Nominal average hourly wage cost. [MOSES database reference: Arbetskostnad/timme, hela ekonomin, NR, säsongrensad, SEWEKSAQ].

Dummies:

Impulse dummies are denoted $Iyy(q)$. For example $I96(1)$ is a dummy which is one in 1996, first quarter, and zero in all other quarters in the sample. The shift dummy x_s_t is proxying a shift in export shares from 2004(1).