CENTRE FOR DYNAMIC MACROECONOMIC ANALYSIS
CONFERENCE PAPERS 2008

CDMC08/01

Testing a DSGE model of the EU using indirect inference*

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SEPTEMBER 2008

ABSTRACT

We use the method of indirect inference, using the bootstrap, to test the Smets and Wouters model of the EU against a VAR auxiliary equation describing their data; the test is based on the Wald statistic. We find that their model generates excessive variance compared with the data. But their model passes the Wald test easily if the errors have the properties assumed by SW but scaled down. We compare a New Classical version of the model which also passes the test easily if error properties are chosen using New Classical priors (notably excluding shocks to preferences). Both versions have (different) difficulties fitting the data if the actual error properties are used.

JEL Classification: C12, C32

Key Words: Bootstrap, DSGE Model, VAR model, Model of EU, indirect inference, Wald statistic.

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*We are grateful for helpful comments on earlier drafts to Matthew Canzoneri, Harris Dellas, Casper de Vries, Alessandro Flamini, Max Gillman, John Hunter, Adrian Pagan, and Christoph Thoenissen. We also thank Konstantinos Theodoridis for his substantial input in the early stages of this work. None of those mentioned bears any responsibility for errors in the present version of the paper.

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1 Introduction

In a notable recent contribution Smets and Wouters (2003) proposed a dynamic stochastic general equilibrium (DSGE) model of the EU which they estimated by Bayesian methods after allowing for a complete set of pre-specified, but ad hoc, stochastic shocks. They reported that, based of measures of fit and dynamic performance, their model was superior in performance both to a Bayesian and a standard VAR. In this paper we look carefully at their innovative model and review its performance, using a new evaluation procedure that is suitable for either a calibrated or, as here, an estimated structural model. The method is based on indirect inference. It exploits the properties of the model's error processes through bootstrap simulations. We ask whether the simulated data of a calibrated or an estimated structural model, treated as the null hypothesis, can explain the actual data where both are represented by the dynamic behaviour of a well-fitting auxiliary model such as a VAR. Our proposed test statistic is a multi-parameter portmanteau Wald test that focuses on the structural model's overall capacity to replicate the data's dynamic performance.

The Smets-Wouters (SW) model follows the model of Christiano et al. (2005) for the US but is fitted to the data using Bayesian estimation methods that allow for a full set of shocks. It is a New-Keynesian model, i.e. it is based on the New Neo-Keynesian Synthesis involving a basic Real Business Cycle framework under imperfect competition in which there are menu costs of price and wage change modelled by Calvo contracts and a backward-looking indexation mechanism; monetary policy is supplied by an interest-rate setting rule. The effect is to impart a high degree of nominal rigidity to the model, both of prices and inflation. A central tenet of New-Keynesian authors is that this is necessary in order to fit the dynamic properties of the data which are characterised by substantial persistence in output and inflation, and hump-shaped responses to monetary policy shocks. In this paper we probe this argument. Specifically, we compare the SW model with a flexprice version in which prices and wages are flexible and there is a physical one quarter lag in the arrival of macro information. Thus our alternative model is a type of 'New Classical' model. We also assess the contribution to the success of their structural model of the ad hoc structural shocks assumed by Smets and Wouters.

Indirect inference has been widely used in the estimation of structural models, see Smith (1993), Gregory and Smith (1991, 1993), Gourieroux et al. (1993), Gourieroux and Monfort (1995) and Canova (2005). Here we make a different use of indirect inference as our aim is to evaluate an already estimated or calibrated structural model. The common element is the use of an auxiliary model. In estimation the idea is to choose the parameters of the structural model so that when this model is simulated it generates estimates of the auxiliary model similar to those obtained from actual data. The optimal choice of parameters for the structural model are those that minimise the distance between a given function of the two sets of estimated coefficients of the auxiliary model. Common choices of this function are the actual coefficients, the scores or the impulse response functions. In model evaluation the parameters of the structural model are given. The aim is to compare the performance of the auxiliary model estimated on simulated data from the given structural model with the performance of the auxiliary model when estimated from actual data. The comparison is based on the distributions of the two sets of parameter estimates of the auxiliary model, or of functions of these estimates.

We find that the properties of the prior distributions of the parameters and the stochastic shocks, whether assumed or generated from the observed data, are the key element in the success or failure of both the Smets-Wouters model and our New Classical variant. The more the error properties conform to New Keynesian priors where there is considerable price stickiness and demand shocks are dominant, the better the Smets-Wouters model performs and the worse our New Classical is. But, in contrast, the more the errors conform to New Classical priors, the better this model performs and the worse the Smets-Wouters model is. Further investigation reveals that only a small degree of price stickiness incorporated in the New Classical model is sufficient to allow it to fit the data well. This suggests that price stickiness, whilst relevant, is not as important as might be suggested by the results of Smets and Wouters.

We begin by describing our model evaluation procedure in section 2 and relate it to estimation by indirect inference. In section 3 we describe the SW model and its findings based on its own detrended data (which we use throughout this paper). In section 4 we apply our proposed testing procedure to the model and compare its performance with a New Classical version of the model, and section 5 concludes.

2 Model evaluation by indirect inference

The aim is to evaluate an already estimated or calibrated (DSGE) macroeconomic model by indirect inference. By evaluate we mean carry out classical statistical inference on the estimated or calibrated model. This is related to, but is different from, estimating a macroeconomic model by indirect inference. The common feature is the use of an auxiliary model in addition to the structural macroeconomic model. Before considering model evaluation by indirect inference, we discuss estimation by indirect inference.

2.1 Estimation

Estimation by indirect inference chooses the parameters of the macroeconomic model so that when this model is simulated it generates estimates of the auxiliary model similar to those obtained from the observed data. The optimal choice of parameters for the macroeconomic model are those that minimize the distance between a given function of the two sets of estimated coefficients of the auxiliary model. Common choices of this function are (i) the actual coefficients, (ii) the scores, and (iii) the impulse response functions. In effect, estimation by indirect inference gives the optimal calibration.

Suppose that y_t is an $m \times 1$ vector of observed data, $t = 1, ..., T$, $x_t(\theta)$ is an $m \times 1$ vector of simulated time series generated from the structural macroeconomic model, θ is a $k \times 1$ vector of the parameters of the macroeconomic model and $x_t(\theta)$ and y_t are assumed to be stationary and ergodic. The auxiliary model is $f[y_t, \alpha]$. We assume that there exists a particular value of θ given by θ_0 such that $\{x_t(\theta_0)\}_{s=1}^{S}$ and $\{y_t\}_{t=1}^{T}$ share the same distribution, i.e.

$$f[x_t(\theta_0), a] = f[y_t, \alpha]$$

where α is the vector of parameters of the auxiliary model.

The likelihood function for the auxiliary model defined for the observed data $\{y_t\}_{t=1}^{T}$ is

$$\mathcal{L}_T(y_t; \alpha) = \Sigma_{t=1}^{T} \log f[y_t, \alpha]$$

The maximum likelihood estimator of α is then

$$a_T = \arg\max_{\alpha} \mathcal{L}_T(y_t; \alpha)$$

The corresponding likelihood function based on the simulated data $\{x_t(\theta)\}_{s=1}^{S}$ is

$$\mathcal{L}_S[x_t(\theta); \alpha] = \Sigma_{t=1}^{S} \log f[x_t(\theta), \alpha]$$

with

$$a_S(\theta) = \arg\max_{a} \mathcal{L}_S[x_t(\theta); \alpha]$$

The simulated quasi maximum likelihood estimator (SQMLE) of θ is

$$\theta_{T,S} = \arg\max_{\theta} \mathcal{L}_T[y_t; \alpha_S(\theta)]$$

This is the value of θ that produces a value of α that maximises the likelihood function using the observed data. We suppose that the observed and the simulated data are such that this value of α satisfies

$$plim\ a_T = plim\ a_S(\theta) = \alpha$$

hence the assumption that $x_t(\theta)$ and y_t are stationary and ergodic, see Canova (2005). It can then be shown that

$$\begin{aligned} T^{1/2}(a_S(\theta) - \alpha) &\rightarrow N[0, \Omega(\theta)] \\ \Omega(\theta) &= E[-\frac{\partial^2 \mathcal{L}[\alpha(\theta)]}{\partial \alpha^2}]^{-1} E[\frac{\partial \mathcal{L}[\alpha(\theta)]}{\partial \alpha} \frac{\partial \mathcal{L}[\alpha(\theta)]}{\partial \alpha}'] E[-\frac{\partial^2 \mathcal{L}[\alpha(\theta)]}{\partial \alpha^2}]^{-1} \end{aligned}$$

The covariance matrix can be obtained either analytically or by bootstrapping the simulations.

The extended method of simulated moments estimator (EMSME) is obtained as follows. Consider the continuous $p \times 1$ vector of functions $g(a_T)$ and $g(\alpha_S(\theta))$ which could, for example, be moments or scores, and let $G_T(a_T) = \frac{1}{T}\Sigma_{t=1}^{T} g(a_T)$ and $G_S(\alpha_S(\theta)) = \frac{1}{S}\Sigma_{s=1}^{S} g(\alpha_S(\theta))$. We require that $a_T \rightarrow \alpha_S$ in probability and that $G_T(a_T) \rightarrow G_S(\alpha_S(\theta))$ in probability for each θ. The EMSME is

$$\theta_{T,S} = \arg\min_{\theta}[G_T(a_T) - G_S(\alpha_S(\theta))]' W(\theta)[G(a_T) - G_S(\alpha_S(\theta))]$$

2.2 Model evaluation

The parameters of the macroeconomic model and their distributions are taken as given — either estimated or calibrated. The aim is to compare the performance of the auxiliary model based on observed data with its performance based on simulations of the macroeconomic model derived from the given distributions of the parameters. The test statistic is based on the distributions of these functions of the parameters of the auxiliary model, or of a function of these parameters. We choose the auxiliary model to be a VAR and base our test on a function of the VAR coefficients.

Non-rejection of the null hypothesis is taken to indicate that dynamic behaviour of the macroeconomic model is not significantly different from that of the observed data. Rejection is taken to imply that the macroeconomic model is incorrectly specified. Comparison of the impulse response functions of the observed and simulated data should reveal in what respects the macroeconomic model fails to capture the auxiliary model.

A Wald test statistic is obtained as follows. We assume that there exists a particular value of θ given by θ_0 such that $\{x_t(\theta_0)\}_{s=1}^{S}$ and $\{y_t\}_{t=1}^{T}$ share the same distribution, where $S = cT$ and $c \geq 1$. If $\widehat{\theta}$ is the estimated or calibrated value of θ then the null hypothesis can be expressed as

$H_0 : \widehat{\theta} \to \theta_0$. Consider again the continuous $p \times 1$ vector of functions $g(a_T)$, $g(\alpha_S(\theta))$, $G_T(a_T) = \frac{1}{T}\Sigma_{t=1}^{T} g(a_T)$ and $G_S(\alpha_S(\theta)) = \frac{1}{S}\Sigma_{s=1}^{S} g(\alpha_S(\theta))$. The functions $g(.)$ may be impulse functions. Given an auxiliary model and a function of its parameters, our test statistic for evaluating the macroeconomic model is based on the distribution of $G_T(a_T) - G_S(\alpha_S(\widehat{\theta}))$. The resulting Wald statistic is

$$[G_T(a_T) - G_S(\alpha_S(\widehat{\theta}))]' W(\widehat{\theta})[G_T(a_T) - G_S(\alpha_S(\widehat{\theta}))]$$

where the estimate of the optimal weighting matrix is

$$W(\widehat{\theta}) = \{[\frac{\partial G(\alpha(\widehat{\theta}))}{\partial \alpha}]\Omega(\widehat{\theta})[\frac{\partial G(\alpha(\widehat{\theta}))}{\partial \alpha}]'\}^{-1}$$

Alternatively, the distribution of $G_T(a_T) - G_S(\alpha_S(\widehat{\theta}))$ and the Wald statistic can be obtained using the bootstrap. We take the following steps in our implementation of the Wald test by bootstrapping:

Step 1: Determine the errors of the economic model conditional on the observed data and $\widehat{\theta}$.

Solve the DSGE macroeconomic model for the structural the errors ε_t given $\widehat{\theta}$ and the observed data. The number of independent structural errors is taken to be less than or equal to the number of endogenous variables. The errors are not assumed to be Normal

Step 2: Construct the empirical distribution of the structural errors

On the null hypothesis the $\{\varepsilon_t\}_{t=1}^{T}$ errors are omitted variables. Their empirical distribution is assumed to be given by these structural errors. The simulated disturbances are drawn from these errors. In some DSGE models the structural errors are assumed to be generated by autoregressive processes. This is the case with the SW model; we discuss below the precise assumptions made.

Step 3: Compute the Wald statistic

The test is here based on a comparison of the VAR coefficient vector itself rather than a multi-valued function of it such as the IRFs.Thus

$$g(a_T) - g(\alpha_S(\theta)) = a_T - \alpha_S(\theta)$$

also therefore

$$G_T(a_T) - G_S(\alpha_S(\widehat{\theta})) = a_T - \alpha_S(\widehat{\theta})$$

The distribution of $a_T - \alpha_S(\widehat{\theta})$ and its covariance matrix $W(\widehat{\theta})^{-1}$ are estimated by bootstrapping $\alpha_S(\widehat{\theta})$. This proceeds by drawing N bootstrap samples of the structural model, and estimating the auxiliary VAR on each, thus obtaining N $a_S(\widehat{\theta})$.This set of vectors represents the sampling variation implied by the structural model, enabling its mean, covariance matrix and confidence bounds to be calculated directly. N is generally set to 1000. We can now compute the properties of the model and compare them with those of the data; in particular we examine the model's ability to encompass the variances of the data. Assuming the model can do so, we go on to compute the bootstrap Wald statistic $[a_T - \alpha_S(\widehat{\theta})]'W(\widehat{\theta})[a_T - \alpha_S(\widehat{\theta})]$- for details see appendix B.

Because the Smets-Wouters model is a log-linearised rational expectations DSGE model, and hence there is an exact VAR representation of the model, in principle, analytic methods could be used rather than the bootstrap. Nonetheless, there are two main reasons why we prefer the bootstrap. First, we wish to preserve the actual residuals implied by the structural model. We do not want these contaminated by any auxiliary assumptions relating to the disturbances of the structural errors of the sort used by Smets and Wouters. To this effect we draw the shocks by time vector, so as to preserve their contemporaneous relation.

Second, the structural model will usually have a VAR representation of high order. Many of the coefficients of such a high-order VAR when estimated unrestictedly will be poorly determined and the coefficient matrices of higher-order lags will be sparsely significant. This will tend to diminish the power of out Wald specification test both in tests of the Smets-Wouters model and the variants of it that we wish to compare. We therefore use a VAR(1) as our auxiliary model tp provide a parsimonious description of the 'dynamic facts' against which several models may be compared with high power of discrimination for their ability to match this description.

3 The Smets-Wouters DSGE model of the EU

Following a recent series of papers Smets and Wouters (2003), SW have developed a DSGE model of the EU. This is in most ways an RBC model but with additional characteristics that make it 'New Keynesian'. First there are Calvo wage- and price-setting contracts under imperfect competition in labour and product markets, together with lagged indexation. Second, there is an interest-rate setting rule with an inflation target to set inflation. Third, there is habit formation in consumption. The model is described in full in Appendix A.

Ten exogenous shocks are added to the model. Eight - technical progress, preferences and cost-push shocks - are assumed to to follow independent AR(1) processes. The whole model is then estimated using Bayesian procedures on quarterly data for the period 1970q1–1999q2 for seven euro-area macroeconomic variables: GDP, consumption, investment, employment, the GDP deflator, real wages and the nominal interest rate. It is assumed that capital and the rental rate of capital are not observed. By using Bayesian methods it is possible to combine key calibrated parameters with sample information. Rather than evaluate the DSGE model based only on its sample moment statistics, impulse response functions are also used. The moments and the impulse response functions for the estimated DSGE model are based on the median of ten thousand simulations of the estimated model. A third-order VAR is fitted to the original data and is used to provide the impulse response functions for the original data. We now summarise the main findings of Smets and Wouters.

Comparing the auto-covariances of the VAR and the simulated DSGE model, those from the VAR are generally quite close to those of the DSGE model. The VAR auto-covariances lie within the confidence bands of those for the DSGE model; the bands are, however, quite wide, indicating parameter uncertainty. The main discrepancy concerns the auto-covariances between output and the expected real interest rate. These are higher in the VAR, but the differences are not significant.

Turning to the impulse response functions for the DSGE model, first we consider the responses to a positive productivity shock, ε_t^a. This causes output, consumption and investment to rise, but employment and the utilisation of capital to fall. The real wage also rises, but only gradually. The fall in employment is consistent with evidence on the impulse responses to US productivity shocks, but is in contrast to the predictions of the standard RBC model without nominal rigidities. A possible explanation is that, due to the rise in productivity, marginal cost falls on impact and, as monetary policy does not respond strongly enough to offset this fall, inflation declines gradually. The estimated reaction of monetary policy to a productivity shock is comparable to results for the US.

A positive labour supply shock has a similar effect on output, inflation and the interest rate to a positive productivity shock. Due to the higher persistence of the labour supply shock, the real interest rate is not greatly affected. The main differences compared to a standard RBC model are first that employment also rises in line with output and, second, that the real wage falls significantly. This fall in the real wage leads to a fall in marginal cost and in inflation. A negative wage mark-up shock has similar effects to these, except that the real interest rate rises, and real wages and marginal costs fall more on impact. The effects of a negative price mark-up shock on output, inflation and interest rates are also similar, but the effects on real marginal cost, real wages and the rental rate of capital are opposite in sign.

Positive demand shocks generally cause real interest rates to rise. A positive preference shock, while increasing consumption and output, crowds-out investment. The increase in capacity necessary to satisfy increased demand is delivered by an increase in the utilisation of installed capital and an increase in employment. Increased consumption demand puts pressure on the prices of the factors of production, and both the rental rate on capital and the real wage, rise thereby putting upward pressure on marginal cost and inflation.

A positive government expenditure shock raises output initially, but crowds-out consumption which, due to increases in the marginal utility of working, leads to a greater willingness of households to work. As a result the effects on real wages, marginal costs and prices are small.

A negative monetary policy shock (increase in the interest rate shock η_t^R) has temporary effects on all variables apart from the price level, which falls permanently. For the first few periods, nominal and real short-term interest rates rise, and output, consumption, investment and real wages fall. The maximum effect on investment is about three times as large as that on consumption. Overall, these effects are consistent with other evidence on the euro area, though the price effects in the model are somewhat larger than those estimated in some identified VARs.

A permanent increase in target inflation ($\bar{\pi}_t$) does not have a strong effect on output, consumption, employment, the real wage or the real interest rate, although all rise quickly. It has a larger effect on investment and, of course, causes the price level to rise permanently.

The contribution of each of the structural shocks to variations in the endogenous variables may be obtained from the forecast error variances at various horizons. At the one-year horizon, output variations are driven primarily by the preference shock and the monetary policy shock. In the medium term, both of these shocks continue to dominate, but the two supply shocks (productivity and labour supply) account for about 20% of the forecast error variance. In the long run, the labour supply shock dominates, but the monetary policy shock still accounts for about a quarter of the forecast error in output. The monetary policy shock is transmitted mainly through investment. The price and wage mark-up shocks make little contribution to output variability. Taken together, the two supply shocks, the productivity and the labour shock, account for only 37% of the long-run forecast error variance of output, which is less than is found in most VAR studies. The limited importance of productivity shocks, which explain a maximum of 12% of the forecast error variance of output, is probably due to the negative correlation between output and employment.

In the short run, variations in inflation are mainly driven by price mark-up shocks. This appears to be a very sluggish process, with inflation only gradually responding to current and expected changes in marginal cost. In the medium and long run, preference shocks and labour supply shocks account for about 20% of the variation in inflation, whereas monetary policy shocks account for about 15%.

In summary, in this study by Smets and Wouters three structural shocks explain a significant fraction of output, inflation and interest rates at the medium to long-term horizon: the preference shock, the labour supply shock and the monetary policy shock. In addition, the price mark-up shock is an important determinant of inflation, but not of output, while the productivity shock determines about 10% of output variations, but does not affect inflation. Smets and Wouters do not report corresponding results for government expenditure shocks, though these shocks appear to have a strong temporary effect on output. This suggests that RBC models, with their focus on productivity shocks, do not give an adequate representation of the economy, or even of output, and that the effects of monetary and, possibly, fiscal policy should also be represented in a DSGE macroeconomic model together with labour supply effects.

The model is estimated on quarterly data for the EU, from 1970:1–1999:4. Comparing the estimated parameters with those obtained by other studies, their general conclusion is that they are similar. They also report various other tests: They compare the DSGE model with VAR(p) (where p=1,2,3) and Bayesian VAR(p) through the use of the Marginal Likelihood or the Bayes factor. They also provide impulse response and variance decomposition analysis. Their assessment is that the model behaves satisfactorily.

4 Testing the SW Model using the method of indirect inference

We now apply our proposed testing procedure to this model using throughout the same data for the period 1970–1999 as SW and the same detrended series obtained by taking deviations of all variables from a mean or a linear trend. We appear to replicate the solution of their model with reasonable accuracy; the method used is Dynare (Juillard (2001)). The distribution of SW's impulse response functions (IRFs), which are illustrated here, are obtained from repeated draws out of the structural parameter posterior distributions. The IRFs of our version of their model have been produced from the median of the posterior distribution of their structural parameters, using the loglinearised version of their model that they too used. Of course we cannot know how the IRFs from any particular parameter combination will compare with their distribution; however the combination of median parameters might reasonably be expected to produce IRFs that for the most part lie inside the 95% bounds shown — and this seems to be the case.

We begin by estimating a VAR on the observed data, using the five main observable variables: inflation (quarterly rate), interest rate (rate per quarter), output, investment and consumption (capital stock, equity returns, and capacity utilisation are all constructed variables, using the model's identities; we omit real wages and employment from the VAR) all in units of percent deviation from trend. We focus on a VAR(1) in order to retain power for our tests, this yields 25 coefficients, apart from constants [1].

[1] Higher order VARs, up to third order, are reported in the appendices, but not used for model testing. For

4.1 Evaluating the SW model using SW's own assumed error properties

Our first evaluation of the SW model uses the error properties they themselves assumed (i.e obtained as the posteriors from their Bayesian estimation procedure). This is an important starting point as the properties they report for the model are based on these assumptions and not on the actual errors we will discuss shortly (we need to scale their errors by 0.25). Given that they have estimated the model satisfactorily with these assumed errors, we would expect it to perform well. This is indeed the case.

We notice first that the model's variance bounds comfortably encompass all the variables we focus on. We then find that the model easily passes the Wald test with a statistic of 75.7; all the VAR coefficients bar one lie inside the 95% model bounds. With two marginal exceptions, the IRFs of the VAR (when identified by the model) also lie within the model bounds (again from the model bootstrap distribution of VAR coefficients). The two exceptions are the effect of a consumption shock on the IRFs of inflation and interest rates. Similarly, the gross cross-correlations in the data largely lie within the model bounds. The exceptions are, however, more serious. The interest rate autocorrelation structure and the correlation structure from output to interest rates are under-predicted, as is the correlation structure between consumption and output. Nonetheless, most of the discrepancies are modest (less than 0.2). The variance decomposition is dominated by the shocks to consumer preferences, with the investment shock contributing also to Q and investment itself. Productivity and monetary shocks have little effect.

More details can be found in Appendix C.

We also find that the SWNC model does badly under these error assumptions — see Appendix E. Thus we can summarise this test as confirming the good model performance that SW themselves found with their model under the error posterior assumptions they made, while rejecting the alternative NC version we have created.

4.2 The New Classical version of SW using error properties chosen to suit NC priors

A key claim of Smets and Wouters is that the good performance of their model reflects the importance of price and wage stickiness. In this section we look at a version of SW's model with flexible wages and prices in which we add an information lag for labour supply as in the Lucas (1972) original 'islands' model. In some respects the same idea has been picked up in 'sticky' information;

example a VAR(3) generally shows all models as passing handsomely, having no less than 75 coefficients. The power of the test is extremely weak.

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.67784	2.17487	TRUE	-1.29699
A_C^I	-0.09612	-1.01321	0.71139	TRUE	0.13541
A_C^π	0.01867	-0.02040	0.20112	TRUE	-1.18651
A_C^Y	0.07935	-0.06675	1.26126	TRUE	-1.43262
A_C^R	-0.00824	-0.05480	0.19518	TRUE	-1.24489
A_I^C	-0.02461	-0.08517	0.12605	TRUE	-0.89331
A_I^I	0.91856	0.80536	1.04445	TRUE	-0.22981
A_I^π	-0.01074	-0.01390	0.01436	TRUE	-1.61228
A_I^Y	-0.01190	-0.06222	0.11812	TRUE	-0.83873
A_I^R	-0.00504	-0.01477	0.01963	TRUE	-0.85038
A_π^C	-0.04105	-2.75549	1.36838	TRUE	0.58582
A_π^I	-0.71538	0.00212	4.65028	FALSE	-2.81450
A_π^π	0.68194	0.33816	0.94001	TRUE	0.05555
A_π^Y	-0.00692	-2.00221	1.50416	TRUE	0.27295
A_π^R	-0.01605	-0.37265	0.34662	TRUE	-0.00606
A_Y^C	0.21989	-1.42637	0.58019	TRUE	1.21983
A_Y^I	0.38855	-1.10769	1.14039	TRUE	0.64902
A_Y^π	0.05457	-0.20815	0.08309	TRUE	1.54982
A_Y^Y	0.93795	-0.55498	1.18992	TRUE	1.32594
A_Y^R	0.06281	-0.22013	0.11210	TRUE	1.43788
A_R^C	-0.37666	-1.83366	0.58254	TRUE	0.40611
A_R^I	-0.97612	-3.20523	-0.88981	TRUE	1.76556
A_R^π	-0.05704	-0.22694	0.09598	TRUE	-0.04928
A_R^Y	-0.40669	-1.84650	0.09677	TRUE	0.85200
A_R^R	0.89695	0.60858	0.98785	TRUE	0.91781
	Wald Statistic	75.7			

*t-stat from bootstrap mean

Table 1: VAR Parameters & Model Bootstrap Bounds (SW model with SW rhos and variances)

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	3.2602	10.5080	0.0453	1.8286	0.1013
Upper	16.4491	101.1404	0.2578	8.6823	0.5723
Mean	7.8083	40.1094	0.1164	4.3093	0.2565

Table 2: Variance of Data and Bootstraps for SW's Model with SW rhos and variances

	Prod	Cons	Gov	Inv	Price	Int	Wage	TOTAL
C	0.561	95.276	0.293	2.577	0.092	1.173	0.027	100
I	0.622	79.123	0.036	18.336	0.161	1.689	0.034	100
K	0.499	80.629	0.054	17.609	0.098	1.084	0.028	100
L	3.472	91.455	1.435	2.028	0.105	1.454	0.051	100
π	0.295	95.017	0.033	0.310	3.285	0.880	0.181	100
Q	1.059	51.598	0.007	38.638	0.632	7.973	0.093	100
R	0.447	98.729	0.042	0.325	0.070	0.365	0.021	100
rk	0.546	90.329	0.221	7.749	0.143	0.800	0.212	100
W	0.638	86.600	0.066	7.464	0.699	2.445	2.088	100
Y	0.891	90.848	1.139	4.976	0.159	1.943	0.044	100

Table 3: Variance Decomposition for SW's Model with SW rhos and variances

the difference is that the 'stickiness' of a short lag is solely due to the physical availability (via collection and publication typically) of macro data and not e.g. to 'rational inattention' or other processing costs — cf Mankiw and Reis (2002) and Sims (2003). Such a model with a one-period information lag would correspond to the original ideas of 'New Classical' macroeconomics in which prices and wages were assumed to be flexible subject to available information.

Like Smets and Wouters we assume a set of priors about the error properties but, in contrast, we assume processes in keeping with New Classical thinking. But, apart from our adaptation to NC form, we adopt SW's parameters and assume a simpler Taylor Rule, of the form $R_t - E_t\pi_{t+1} = 1.5(\pi_t - \pi^*)$.. Our NC alternative might appear to be handicapped by using parameters estimated under NK priors; however it turns out that the key assumptions are about the errors. We followed many authors of Real Business Cycle models in assuming zero shocks to consumer and investment preferences; otherwise we simply used the actual shocks generated by the data and the NC model to find both their variance and their AR parameters (details of these actual errors are given below), scaling the errors by only 0.7.

The remarkable thing about this exercise is that this version of the model SWNC is also highly compatible with the data. It seems that if one chooses suitable error properties one can match both NK and NC versions of the model! We find that the data variances of our key variables all lie inside the model's 95% bounds, with a marginal exception of consumption. Then the SWNC model has a Wald statistic of 85.0, with only one VAR coefficient lying outside the 95% bounds. The model's variance decomposition is now dominated for real variables by productivity and labour supply (wage) shocks; and for nominal variables by labour supply and monetary (inflation) shocks. The VAR IRFs for real variables under the productivity and labour supply shocks lie outside the model 95% bounds — the model underestimates them. For nominal they are close for these shocks and inside for the monetary shock. The cross-correlations all lie inside the 95% model bounds, with the exceptions of the cross-correlations with output of both inflation and interest rates which are somewhat more positive than the model bounds.

Thus again we find that SWNC fits well when the errors are chosen using NC priors; furthermore the SWNK fits badly under these NC priors — see Appendix J.

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.38922	1.00516	TRUE	0.99529
A_C^I	-0.09612	-0.83115	0.13808	TRUE	1.11278
A_C^π	0.01867	-0.15051	0.22081	TRUE	-0.09127
A_C^Y	0.07935	-0.31773	0.33397	TRUE	0.42883
A_C^R	-0.00824	-0.25663	0.33100	TRUE	-0.24559
A_I^C	-0.02461	-0.06432	0.06105	TRUE	-0.60798
A_I^I	0.91856	0.84056	1.02208	TRUE	-0.43247
A_I^π	-0.01074	-0.03590	0.03334	TRUE	-0.58558
A_I^Y	-0.01190	-0.04825	0.07188	TRUE	-0.70474
A_I^R	-0.00504	-0.05913	0.05865	TRUE	-0.19061
A_π^C	-0.04105	-0.11680	1.21684	TRUE	-1.87390
A_π^I	-0.71538	0.39292	2.45209	FALSE	-4.10970
A_π^π	0.68194	0.59311	1.31572	TRUE	-1.56029
A_π^Y	-0.00692	-0.13882	1.09768	TRUE	-1.62757
A_π^R	-0.01605	-0.27846	1.01944	TRUE	-1.15563
A_Y^C	0.21989	-0.09905	0.43690	TRUE	0.37025
A_Y^I	0.38855	-0.03180	0.76454	TRUE	0.12325
A_Y^π	0.05457	-0.18409	0.13951	TRUE	0.90608
A_Y^Y	0.93795	0.54713	1.06406	TRUE	0.81169
A_Y^R	0.06281	-0.30796	0.22601	TRUE	0.67308
A_R^C	-0.37666	-1.23808	-0.19850	TRUE	1.19908
A_R^I	-0.97612	-2.70167	-0.90465	TRUE	1.84734
A_R^π	-0.05704	-0.40124	0.21020	TRUE	0.21640
A_R^Y	-0.40669	-1.12134	-0.07573	TRUE	0.80559
A_R^R	0.89695	0.02191	1.00569	TRUE	1.41461
	Wald Statistic	85.0			

*t-stat from bootstrap mean

Table 4: VAR Parameters & Model Bootstrap Bounds (Flex with NC Priors)

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	0.6578	4.8250	0.0986	0.5769	0.1910
Upper	6.4263	56.6121	0.3985	5.3142	0.6991
Mean	2.3265	20.6644	0.2055	1.9926	0.3864

Table 5: Variance of Data and Bootstraps for Flex Model with NC Priors

	Prod	Gov	Monetary	Labour Supply	TOTAL
C	35.621	0.388	0.032	63.959	100
I	30.511	0.240	0.001	69.248	100
K	36.036	0.141	0.000	63.823	100
L	25.702	2.225	0.046	72.026	100
π	2.543	0.643	84.751	12.064	100
Q	18.231	1.804	0.759	79.206	100
R	8.928	2.185	46.138	42.749	100
rk	32.623	0.686	0.010	66.681	100
W	83.989	0.163	0.002	15.846	100
Y	34.674	1.190	0.025	64.111	100

Table 6: Variance Decompositon for Flex Model with NC Priors

4.3 The actual disturbances implied by the model compared with the assumed errors

So far we have supplied both the NK and NC versions of the SW model with essentially imaginary error properties, chosen by assumption. We now turn to the actual errors derived from using the observed data; we use 'actual errors' from now on to describe the model's structural residuals, that is the residual in each equation given the actual data and the expected variables in it[2] — see Figure 1. There are six behavioural errors: consumption, investment, productivity, interest rates (monetary policy), wage- and price-setting, and one exogenous process, government spending, which only enters into the goods market-clearing equation (or 'GDP identity'). The first error is that of the Euler equation and has a standard error of 0.5(%), roughly half as much again as assumed by SW (see Canzoneri et al. (2007) on the peculiarities of actual Euler equation errors), that for investment in the second has a standard error of 1.2%, around ten times that assumed by SW. Furthermore the AR coefficients (ρs) of the structural residuals are very different; there is hardly any persistence in the estimated residuals for consumption and investment, unlike the high persistence assumed by SW. In contrast, the actual inflation and Taylor Rule errors are persistent and not zero, as assumed. The Table below shows the comparison between SW's assumed shocks and those shown in the graphs below. These differences will turn out to be an important factor in the tests we will carry out.

Using the errors assumed by SW we proceeded to bootstrap their model with the median parameters whose IRFs are shown in Appendix F and were discussed above. The resulting variables' bootstrap variances are massively in excess of those of the structural residuals calculated from the observed data — about 16 times larger. Thus the model fails to replicate the data in a rather basic way. Such findings are not uncommon in models with calibrated parameters especially where, as

[2] Under our procedure the exact way to derive these is to generate the model's own expected variables conditional on available information each period. These errors being calculated, AR processes are estimated for them. The SW model can then be bootstrapped using the random elements in these error processes. To find these errors one needs to iterate between the errors used to project the model expectations and the resulting errors when these expectations are used to calculate the errors. This procedure is complex and has so far produced large and implausible errors.

In practice we used an alternative procedure to calculate the errors, which avoids this need to iterate. We projected the expected variables from the VAR(1) estimated above. Since this VAR is not the exact model but is merely a convenient description of the data, under the null hypothesis of the structural DSGE model these expected variables will be the model's true expectations plus approximation errors. We conjecture that this will lower the power of the Wald statistic but only negligibly; to test this conjecture heuristically we raise the order of the VAR used to project the expectations and see whether it affects the results. We know that the model has a VAR representation if it satisfies the Blanchard-Kahn conditions for a well-behaved rational expectations model, as is assumed and checked by Dynare. As the order of the VAR rises it converges on this exact representation, steadily reducing the degree of the approximation. Hence if the results do not change as the VAR order rises, it implies that the approximation error has trivial effects. This is what we found when we raised the order from 1 to 3 (for example the Wald statistic moved from 92.9 to 94.6; the model's interest rate variance lower 95% bound moved from 0.024 to 0.025). We are also investigating further ways to solve for the exact expectations.

It should also be noted that we excluded the first 20 error observations from the sample because of extreme values; we also smoothed two extreme error values in Q. Thus our sample for both bootstraps and data estimation was 98 quarters, i.e. 1975(1)-1999(2).

Variances	Cons	Inv	Inflation	Wage	Gov	Prod	Tayl rle
Data var	0.26	1.52	0.0007	0.278	0.141	0.091	0.227
SW var	0.088	0.017	0.026	0.081	0.108	0.375	0.017
Ratio	2.9	89	0.03	3.4	1.3	0.24	13.4
ρ							
Data	-0.101	0.063	0.154	-0.038	0.751	0.940	0.565
SW	0.886	0.917	0	0	0.956	0.828	0

Table 7: Variances of innovations and AR Coefficients (rhos) of shocks (data-generated v. SW assumed shocks)

here, tight bounds are placed on the model variances to adjust them to match, say, the overall variance of GDP. Under such a procedure it would be open to the authors to assume that the latent errors simply need to be scaled down — this was what we did above with the assumed error properties.

The problem is more serious when the structural residuals are used. The inability of the model to capture the scale of the variances of the data represents a real model failure. In order to take further tests seriously we need to have a means to set the poor variance fit on one side. We do so by notionally dividing the effect of the model disturbances into two parts: the impact effect and the effect through lags of both the errors and the endogenous variables. We could think of the model's failure as reflecting the excessive size of the impact effect. We could then scale down this impact effect, assuming that some misspecification could be isolated that is responsible for its excessive size. We can then investigate the models' lag effects or 'transmission process' — as summarised in the VAR coefficients. We note that the impact effect results from the whole model structure and whatever misspecification is responsible will also affect the lag transmission process. Nevertheless we suppose for purposes of further investigation alone that it would be possible to modify the impact effect while maintaining the transmission process.[3] Our scaling procedure is in general the same for all errors. We choose the scaling factor separately for each model version in such a way that the 95% bounds on the bootstraps contain the variances of the data. For the SW model as above the scaling factor needed is 0.25. In the context of SW's methods we can think of this as choosing lower error standard deviations by this amount.

[3] Let the model be given by $Ay_t = ME_t y_{t+1} + Ny_{t-1} + u_t$, where $u_t = \Phi u_{t-1} + \epsilon_t$. This can be transformed into $y_t = A^{-1}MB^{-1}y_t + A^{-1}NLy_t + A^{-1}u_t$; where L is the lag operator and B^{-1} is the forward operator leading the variable while keeping the date of expectations constant (here at t). Assume that the model satisfies the saddlepath Blanchard-Kahn conditions (with f forward and l backward roots), then we can rewrite it as $\prod_{i=1}^{f}(I - \gamma_i B^{-1}) \prod_{j=1}^{l}(I - \lambda_j L)y_t = K(L; M, N, A)u_t$.Here we note that K is a function of all the parameters of the model, as well as involving lags of the errors produced by the backward roots and current values of the errrors produced by the forward roots. We can solve for y_t in terms of the current shocks and its own lagged values by projecting the forward roots onto the errors and then projecting all the backward roots, as well as error autoregressive roots, onto y_t. It is clear that the impact effect, just like the transmission effect, comes from the complete parameter set.

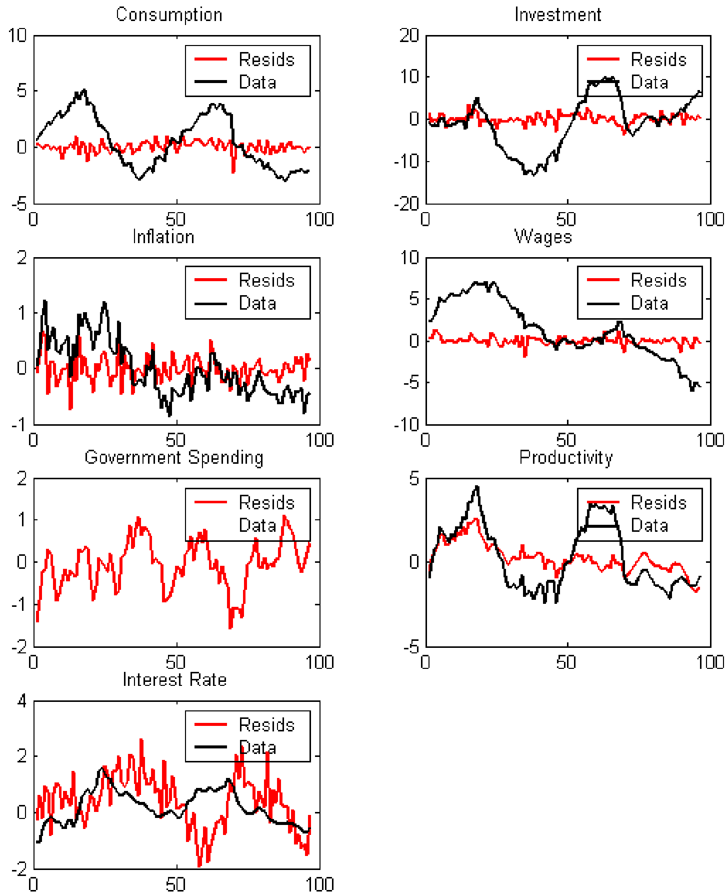

Figure 1: Single Equation Errors from SW Model

4.4 The SW New Keynesian model using actual errors

Here we take the structural residuals implied by the data and base the model's behaviour on these. We then re-estimate the error processes with new autoregressive parameters (ρs). Bootstrapping their random components — drawing them as vectors to preserve any dependence between them — we get the results in Table 8 below. We have scaled the errors by 0.25; although the variances of the errors are much higher than SW's, their autocorrelation is far less so that the two effects cancel out in terms of the model's simulated variances.

The results are rather mixed.The model is accepted on the VAR coefficients at the 5% level, with a Wald statistic of 93.6. Thus on the basic metric we are using it passes marginally. However, the model cannot reproduce the data variances, even with the heavy scaling we have used (Table 9). For interest rates the data variance lies very far above the model's upper bound; while for investment it lies rather below the model's lower bound. Out of the twenty-five VAR coefficients only four lie outside their 95% bounds which is consistent with passing the Wald test. Three of these coefficients concern interest rate effects, as one might expect from the model's failure to capture the variance of the interest rate. The remaining concern is investment, for which the model variance is greatly excessive.

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	-0.72761	1.56433	TRUE	0.72681
A_C^I	-0.09612	-3.67952	1.97243	TRUE	0.52460
A_C^π	0.01867	-0.25012	0.15093	TRUE	0.63888
A_C^Y	0.07935	-1.18984	0.97379	TRUE	0.32915
A_C^R	-0.00824	-0.10728	0.07514	TRUE	0.20002
A_I^C	-0.02461	-0.12365	0.02746	TRUE	0.49674
A_I^I	0.91856	0.59652	0.96120	TRUE	1.49397
A_I^π	-0.01074	-0.01690	0.00811	TRUE	-1.04404
A_I^Y	-0.01190	-0.08305	0.05315	TRUE	0.02955
A_I^R	-0.00504	-0.00099	0.00983	FALSE	-3.34577
A_π^C	-0.04105	-0.63612	2.05088	TRUE	-1.17884
A_π^I	-0.71538	1.97340	9.92243	FALSE	-3.58523
A_π^π	0.68194	0.54220	1.11755	TRUE	-1.41208
A_π^Y	-0.00692	-0.36242	2.13874	TRUE	-1.51517
A_π^R	-0.01605	-0.08937	0.11765	TRUE	-0.53770
A_Y^C	0.21989	-0.81029	1.85980	TRUE	-0.36596
A_Y^I	0.38855	-2.35381	4.09609	TRUE	-0.23243
A_Y^π	0.05457	-0.16908	0.27962	TRUE	0.03882
A_Y^Y	0.93795	-0.32156	2.14998	TRUE	0.09489
A_Y^R	0.06281	-0.11977	0.08366	TRUE	1.50196
A_R^C	-0.37666	-4.28405	-0.20281	TRUE	1.75415
A_R^I	-0.97612	-7.78487	1.53307	TRUE	0.89647
A_R^π	-0.05704	-0.65743	-0.00702	TRUE	1.62513
A_R^Y	-0.40669	-4.19901	-0.44180	FALSE	1.99106
A_R^R	0.89695	0.45640	0.75317	FALSE	3.78248
	Wald Statistic	93.6			

*t-stat from bootstrap mean

Table 8: VAR Parameters & Model Bootstrap Bounds (SW with estimated rhos)

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	3.5651	47.5781	0.0745	3.3518	0.0244
Upper	23.6006	409.0063	0.3819	22.1150	0.0808
Mean	10.2900	168.5409	0.1857	9.8493	0.0442

Table 9: Variance of Data and Bootstraps for SW's Model (with estimated rhos)

Turning to the VAR IRFs it can be seen (Appendix G) that rejections are scattered across the five variables in our VAR and also across the structural shocks. In particular, we find that the interest rate responses are well outside their permitted bounds for most shocks. This is consistent with the model's failure to capture the variance of the interest rate. We show a number of these

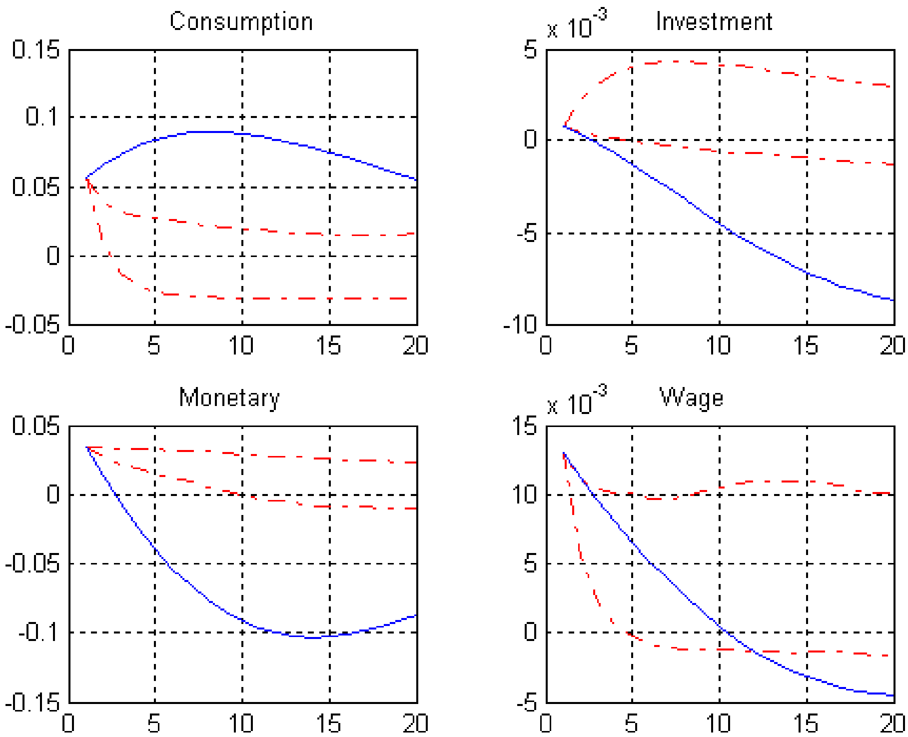

Figure 2: Interest Rate Responses to Various Shocks with 95% Bounds (SW with estimated ρ's)

below.

The cross-correlations (see Appendix G) reveal that the model underpredicts the autocorrelation of consumption and badly underpredicts the positive data cross-correlations of both consumption and investment with output (both from lagged output to consumption and investment and from lagged consumption and investment to output).

What seems to be undermining the model's performance is the virtual elimination of the autocorrelation in both the main demand shocks, consumption and investment. This is what generates the poor prediction of the persistence and cross-correlations for the real variables. It also produces too little interest rate variation because inflation and so interest rates respond less to less persistent shocks. The overwhelmingly dominant shock is now that to the Taylor Rule, because it has a high variance (it includes all the shocks to potential output) as well as moderate persistence.

Thus in summary the SW model fails in several important ways to match the data, once actual error behaviour is substituted for assumed behaviour. The reason is the drop in persistence of the actual demand shocks compared with SW's assumed shocks.

4.5 The New Classical Version of SW using actual errors

The NC model has enormous problems in fitting nominal data variances when the actual errors are used, even though it now requires scaling by only 0.67 and passes the Wald test comfortably with a value of 76.8. It overpredicts both inflation and interest rate variances both of which lie rather below the model's lower 95% bound. This is reflected in the four VAR coefficients that lie outside their bounds: the cross-effects from inflation and interest rates to consumption and from inflation on interest rates, all of which the model makes excessively negative, and the partial autocorrelation of interest rates which the model greatly underpredicts. The excessive variation in inflation and associated interest rates produces low interest rate persistence; and the model generates from it high negatively correlated responses of consumption..

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.52259	1.18525	TRUE	0.12292
A_C^I	-0.09612	-0.96369	1.27543	TRUE	-0.42842
A_C^π	0.01867	-0.97493	-0.01531	FALSE	1.96524
A_C^Y	0.07935	-0.17288	0.45474	TRUE	-0.36065
A_C^R	-0.00824	-1.23870	-0.03653	FALSE	1.97025
A_I^C	-0.02461	-0.06602	0.04563	TRUE	-0.69450
A_I^I	0.91856	0.68911	1.07953	TRUE	0.19148
A_I^π	-0.01074	-0.07240	0.09956	TRUE	-0.49211
A_I^Y	-0.01190	-0.04235	0.05387	TRUE	-0.76602
A_I^R	-0.00504	-0.08904	0.12880	TRUE	-0.37198
A_π^C	-0.04105	-0.94409	1.02284	TRUE	-0.29536
A_π^I	-0.71538	-2.79046	4.28830	TRUE	-0.92632
A_π^π	0.68194	0.16140	3.20631	TRUE	-1.45758
A_π^Y	-0.00692	-0.84830	1.03652	TRUE	-0.30382
A_π^R	-0.01605	-0.60757	3.17618	TRUE	-1.52104
A_Y^C	0.21989	-0.31978	0.50850	TRUE	0.56298
A_Y^I	0.38855	-1.38295	1.34478	TRUE	0.53247
A_Y^π	0.05457	-0.35789	0.84976	TRUE	-0.60112
A_Y^Y	0.93795	0.38835	1.13783	TRUE	0.85587
A_Y^R	0.06281	-0.39085	1.05363	TRUE	-0.64525
A_R^C	-0.37666	-0.81912	0.73652	TRUE	-0.80463
A_R^I	-0.97612	-3.31798	2.22810	TRUE	-0.18695
A_R^π	-0.05704	-2.57757	-0.25199	FALSE	2.37433
A_R^Y	-0.40669	-0.78257	0.66123	TRUE	-0.81601
A_R^R	0.89695	-2.64767	0.23123	FALSE	2.91387
	Wald Statistic	76.8			

*t-stat from bootstrap mean

Table 10: VAR Parameters & Model Bootstrap Bounds (Flexprice Model)

The same story shows up in the IRFs. The dominant shocks on real variables are now the labour supply (wage) and productivity shocks while for nominal variables they are consumption, monetary and labour supply. We find that the responses of consumption and output to labour supply and productivity lie well outside the rather narrow model 95% bounds, reflecting the model's

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	0.7330	9.8999	0.4497	0.6434	0.6906
Upper	6.8787	84.0695	0.9583	5.6327	1.4368
Mean	2.4783	34.5926	0.6678	2.2226	1.0270

Table 11: Variance of Data and Bootstraps for Flex-Price Model

	Prod	Cons	Gov	Inv	Price	Wage	TOTAL
C	35.360	0.237	0.385	0.495	0.032	63.491	100
I	27.903	0.060	0.219	8.488	0.001	63.329	100
K	34.697	0.027	0.135	3.689	0.000	61.451	100
L	25.517	0.278	2.209	0.442	0.046	71.508	100
π	1.739	31.512	0.440	0.083	57.973	8.252	100
Q	15.320	13.421	1.516	2.547	0.638	66.558	100
R	5.607	36.900	1.372	0.301	28.975	26.846	100
rk	31.196	0.090	0.656	4.285	0.010	63.763	100
W	83.085	0.022	0.161	1.053	0.002	15.675	100
Y	34.437	0.152	1.182	0.531	0.025	63.673	100

Table 12: Variance Decompositon for Flex-Price Model

inadequate variance for these . Those for interest rates and inflation start in or close to the bounds; but thereafter they die off more slowly in the data than in the model. — see Figure 3

We can see the same story too in the cross-correlations. Here the autocorrelations of consumption and output, and also their cross-correlations are picked up well by the model; even though it underpredicts their variance, it has no trouble with their dynamic patterns. However, for inflation and interest rates the model greatly underpredicts their autocorrelations, and also their cross-correlations with output. The excessive variance of both the former due to the model's price-flexibility does not produce enough correlation with persistent output.

So in summary the new classical version of the model too fails to match the data. Here the reason is that the substantial demand shocks produce high variance in inflation and interest rates; because these shocks die out quickly they also produce too little persistence to match the data for these.

If we compare the New Classical with the New Keynesian versions of SW we may note that in the NC supply shocks determine real variables while demand shocks determine nominal ones; whereas in the NK demand shocks dominate both real and nominal variables. SW's original NK model assumed highly persistent demand shocks and these were helpful in matching the data's dynamic patterns. However, withdraw the persistence of these shocks, as we find in the actual errors, and the NK model fails — essentially because it cannot generate enough persistence in real variables. As for the NC version, these demand shocks retain high variance together with low persistence; and this produces the same patterns in nominal variables which now fail to match the

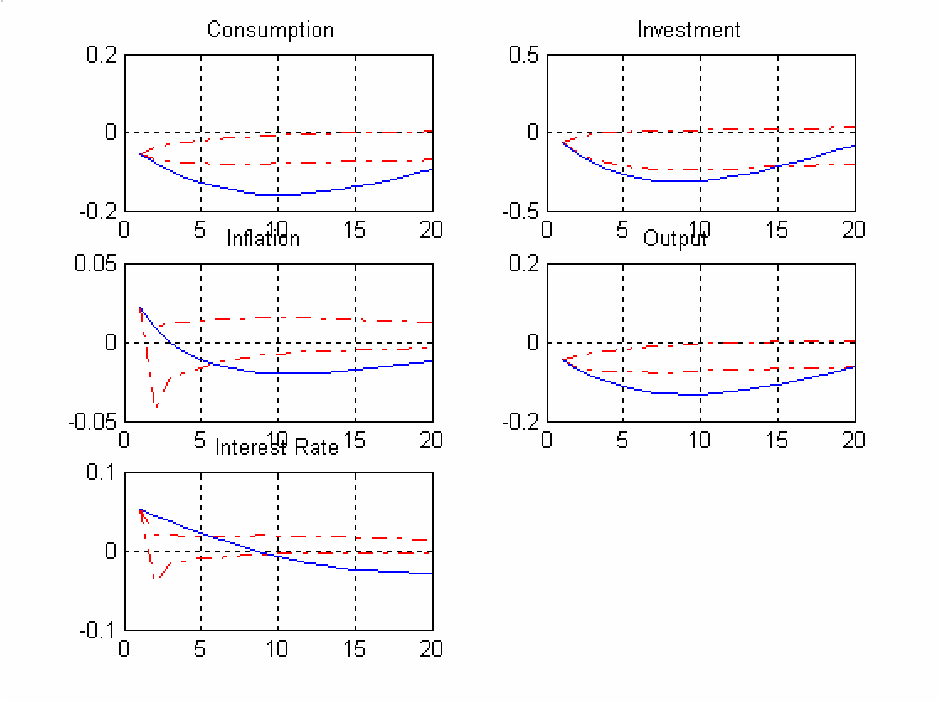

Figure 3: Wage Shock to New Classical Version of SW

data. Real variables are well-matched by the model's response to persistent supply shocks.

4.6 Robustness tests treating the data in alternative ways

We have placed much emphasis on the actual errors implied by the model and the data. This raises the issue of whether the errors are affected in any important way by alternative ways of treating the data. One major issue is that of filtering the data to obtain approximate stationarity. SW simply take out a constant and linear trend. However, this leaves one data-series on the borderline of trend-stationarity: viz wages, though this is not included in our VAR while its error has virtually no autocorrelation. We redid the exercise using the Hodrick-Prescott filter.

Another question that arises is whether the data were affected by non-stochastic elements which acted in the same way as 'trend' factors. Thus we could attempt some division of the errors into 'non-stochastic' (once-for-all events) and stochastic (repetitive events). This is similar to the idea of detrending in the sense that it removes elements that are not properly components of the business cycle. To do this accurately would require us to specify what these once-for-all events were and remove their effects both from the model and from the data, just as in principle we do for 'trend'. Such one-off events over the EU's history includewaves of new membership and German reunification. In another check we redid the exercise after regressing the SW data on a set of dummies for idnetifiable events of this sort — we then took these dummy effects out of the data and used the adjusted data from that point.

Results of both these checks are reported in our Appendices J to M; they make no material difference to our results.

5 Comparing the New Keynesian and New Classical versions of the SW model — a weighted combination?

In this paper we have sought to test the SW model and to asssess its capacity to replicate dynamic features of the data as compared with a quite different model. Such a comparison makes sense if there is still significant controversy about what type of model should be used, and it matters both for understanding events and for making policy. SW made certain prior modelling choices, some of which remain controversial within macroeconomics. One of these was their main innovation, the assumptions relating to the degree of price and wage rigidity in their model. We have re-examined even though the implications of these assumptions at some length by positing a New Classical version of their DSGE model which does not have price and wage stickiness.

We found that the properties of the errors are the key element in the success or failure of both SWNK and SWNC in these tests. The more the error properties conform to NK priors, with dominant demand shocks, the better the SWNK model performs and the worse the SWNC does. In contrast, the more the errors conform to New Classical priors, the better the SWNC performs and the worse SWNK does. When the error properties are derived from observed data, both models have difficulty fitting the data, though SWNC model is probably the closest to doing so. What is the explanation for these results?

In the SWNK model, because capacity utilisation is flexible, demand shocks (consumption/ investment/money) dominate output and - via Phillips Curve - inflation, then - via Taylor Rule - interest rates. Supply shocks (productivity, labour supply, wages/inflation mark-ups) play a minor role as 'cost-push' inflation shocks as they do not directly affect output. Persistent demand shocks raise 'Q' persistently and produce an 'investment boom' which, via demand effects, reinforces itself. Thus the model acts as a 'multiplier/accelerator' of demand shocks. Demand shocks therefore dominate the model, both for real and nominal variables. Moreover, in order to obtain good model perfomance for real and nominal data, these demand shocks need to be of sufficient size and persistence. .

In the SWNC model an inelastic labour supply causes output variation to be dominated by supply shocks (productivity and labour supply) and investment/consumption to react to output in a standard RBC manner. These reactions, together with demand shocks, create market-clearing movements in real interest rates and - via the Taylor rule - in inflation. Supply shocks are prime movers of all variables in the SWNC model, while demand shocks add to the variability of nominal variables. In order to mimic real variability and persistence suitably sized and persistent supply shocks are needed, but to mimic the limited variability in inflation and interest rates only a limited variance in demand shocks is required; and to mimic their persistence the supply shocks must be sufficiently autocorrelated.

The observed demand shocks have too little persistence to capture the variability of real variables in the SWNK model, but they generate too much variability in nominal variables in the SWNC model. The observed supply shocks matter little for the SWNK but are about right in size and persistence for the real variables in the SWNC. The implication is that the flexibility of prices and wages may lie somewhere between New Keynesian and the New Classical models. For example, adding a degree of price and wage stickiness to the SWNC model would bring down the variance of nominal variables, and boost that of real variables in the model.

A natural way to look at this is to assume that wage and price setters find themselves supplying labour and intermediate output partly in a competitive market with price/wage flexibility, and partly in a market with imperfect competition. We can assume that the size of each sector depends on the facts of competition and do not vary in our sample. The degree of imperfect competition could differ between labour and product markets. For the exercise here we will initially assume that it is the same in each market and given by a single free parameter, v. This implies that the price and wage equations will be a weighted average of the SWNK and SWNC equations, with the weights respectively of $(1 - v)$ and v. We will also assume that the monetary authority uses this parameter to weight its New Keynesian and New Classical Taylor Rules as we have found that different values of the parameter v work best for a competitive (NC) model and an imperfect competition (NK) economy. In practice we can think of the weight v as giving the extent of the NC (competitive) share of the economy.

We now choose a value of v for which the combined model is closest to matching the data variances while also passing the Wald test. This is an informal use of indirect inference which provides a broader criterion which better reflects our concerns with the models' perfomance than simply applying a Wald score to, for example, the VAR coefficients. The optimal value turns out to be 0.94. This implies quite a small NK sector of only 6% of the economy, but it is sufficient to bring the overall economy's properties close to the dynamic facts. We allowed the weight to be further varied around this to generate an optimum performance: in labour markets ($v_w = 0.08$), product markets ($v_p = 0.06$), and monetary policy ($v_m = 0.04$). We now consider how good a fit this is.

The key difference is the ability of the model to replicate the variances in the data. No scaling is required and all the data variances lie within the model's 95% bounds (Table 13). The model therefore satisfies the necessary basic conditions for us to take it seriously: it produces behaviour of the right size for both real and nominal variables and the structural errrors are generated from the model using the observed data.

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	1.7200	20.7905	0.2292	1.5284	0.2036
Upper	13.7364	172.3241	0.8405	11.3359	0.7146
Mean	5.0452	69.2529	0.4425	4.4535	0.3764

Table 13: Variance of Data and Bootstraps for the Weighted Model

The Wald test is 90.8 with just three VAR coefficients lying outside their 95% bounds. The main discrepancy is the partial autocorrelation of interest rates which the model underpredicts. The other two coefficients involve the cross-effects of inflation and interest rates on consumption, but they are only marginally outside their bounds.

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.26572	1.02827	TRUE	1.17662
A_C^I	-0.09612	-0.92015	1.19403	TRUE	-0.39647
A_C^π	0.01867	-0.30244	0.08489	TRUE	1.27573
A_C^Y	0.07935	-0.36553	0.28805	TRUE	0.72452
A_C^R	-0.00824	-0.33625	-0.00284	TRUE	1.83460
A_I^C	-0.02461	-0.06640	0.06491	TRUE	-0.75793
A_I^I	0.91856	0.68054	1.05976	TRUE	0.30909
A_I^π	-0.01074	-0.02810	0.05323	TRUE	-1.14494
A_I^Y	-0.01190	-0.04254	0.07168	TRUE	-0.91032
A_I^R	-0.00504	-0.01937	0.04928	TRUE	-1.13906
A_π^C	-0.04105	-0.28473	1.84441	TRUE	-1.51365
A_π^I	-0.71538	-1.68976	4.13846	TRUE	-1.38882
A_π^π	0.68194	0.44617	1.57336	TRUE	-1.23414
A_π^Y	-0.00692	0.08981	1.93824	FALSE	-2.00415
A_π^R	-0.01605	0.10374	1.04049	FALSE	-2.51828
A_Y^C	0.21989	-0.27066	0.71764	TRUE	0.03638
A_Y^I	0.38855	-1.34895	1.33299	TRUE	0.50045
A_Y^π	0.05457	-0.25489	0.27741	TRUE	0.25731
A_Y^Y	0.93795	0.38837	1.25734	TRUE	0.42118
A_Y^R	0.06281	-0.19508	0.25990	TRUE	0.19567
A_R^C	-0.37666	-2.04721	0.26606	TRUE	0.87186
A_R^I	-0.97612	-4.17678	2.09513	TRUE	0.07900
A_R^π	-0.05704	-1.05222	0.07775	TRUE	1.45411
A_R^Y	-0.40669	-2.12602	-0.15480	TRUE	1.28935
A_R^R	0.89695	-0.52286	0.45459	FALSE	3.79338
	Wald Statistic	90.8			

*t-stat from bootstrap mean

Table 14: VAR Parameters & Model Bootstrap Bounds (Weighted Model)

The variance decomposition of real variables is now heavily skewed towards being caused by supply shocks with 75% of the output variance being due in the model to labour supply and productivity shocks. In contrast, nominal variables are dominated by demand shocks with 74% of the variance of inflation due in the model to the shocks to the Taylor Rule. Being the sum of a real variable and expected inflation, about two thirds of the variance of nominal interest rates is due to productivity and labour supply shocks, with the remainder due to shocks to the Taylor Rule (a quarter) and to other demand shocks.

The model bounds for the VAR impulse response functions enclose many of the data-based IRFs for the three key shocks: labour supply, productivity and shocks to the Taylor Rule. The main discrepancies in response to supply shocks are the longer-term predictions of interest rates and inflation which in the data wander further from equilibrium than in the model. Again, apart from the longer-term interest rate predictions, all data-based IRFs for the Taylor Rule demand shock lie inside; these are (as we saw from the VAR coefficient) a lot more persistent in the data than in the model. Hence the model performance based on the IRFs is fairly good, with the main weakness in the interest rate prediction.

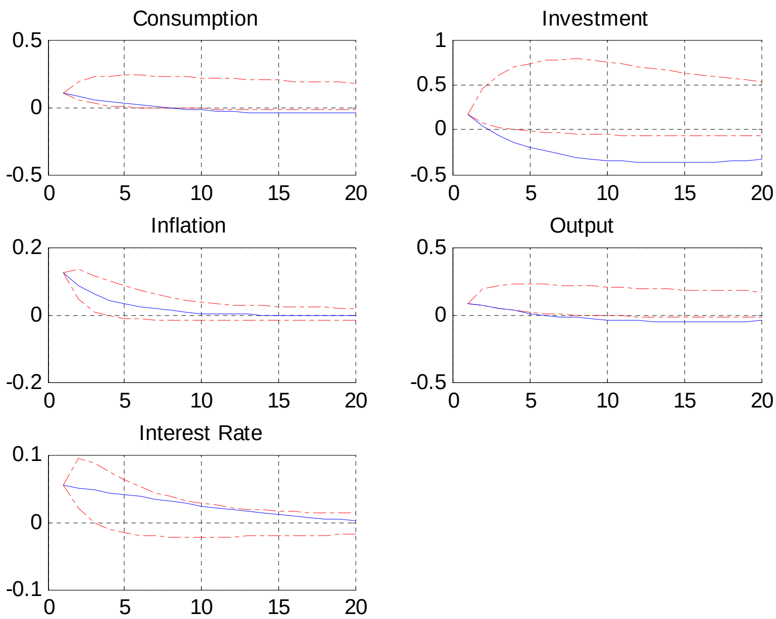

Figure 4: Taylor Rule Shock to Weighted Model

Looking at cross-correlations for the real variables, we find, as for the New Classical model alone, that the data-based correlations all lie inside the model's bounds. Now, however, the weights for NK formulation of price stickiness, although small, produce behaviour in the nominal variables that

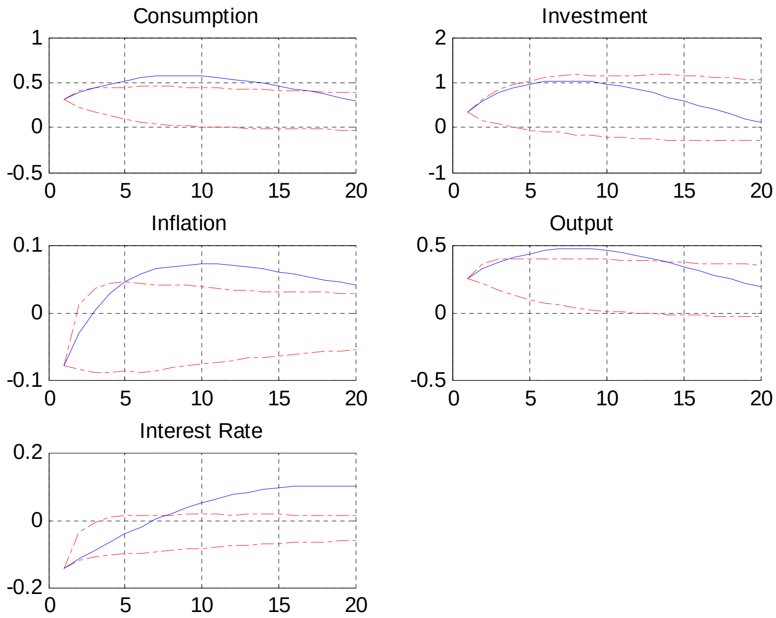

Figure 5: Productivity Shock to Weighted Model

is almost within the 95% bounds of the weighted model (only the interest rate cross-correlation with output lies much outside).

To summarise, we find that a small weight on the NK formulation of price stickiness suffices to get the mixed New Classical - New Keynesian model to pass our tests. There are still some failures, so that the problem of finding a fully satisfactory specification remains. Nonetheless, within the specifications at our disposal here, we can say that the EU economy appears to be closest to a New Classical specification.

We note that these methods could be applied to other features of Smets and Wouters's model. The method of indirect inference permits a variety of explorations of alternative modelling choices while maintaining the overarching DSGE framework. It is possible that it is simply too hard for a DSGE model to pass the tests we propose here (the viewpoint of Canova (1994) and also an early viewpoint of Lucas and Prescott cited in Evans and Honkapohja (2005) for example). But in our experiments here the DSGE models we look at come close enough in some cases to suggest that this is too pessimistic a view.

6 Conclusion

In this paper we have applied the method of indirect inference to testing an influential DSGE model for the EU created by Smets and Wouters (2003). In many key respects this model follows an approach developed by Christiano et al. (2005) for the US. Using indirect inference a structural model's parameters may be chosen to optimise its capacity to replicate the parameters of an auxiliary time-series model whose role is to describe the data parsimoniously. Instead of using indirect inference to estimate the model, here we use it to test the model by deriving the small sample distribution of our test statistic under the null hypothesis that a calibrated or estimated structural DSGE model is correct. The DSGE model's errors are recovered and used for bootstrapping (after whitening); the resulting pseudo-samples are used to obtain the sampling distribution it implies for the parameters of the auxiliary time series model. The test then consists of determining whether functions of the parameters of the time-series (VAR) model estimated on the actual data lie within some confidence interval of this distribution. We use a Wald test statistic to evaluate the overall fit of the DSGE model to the whole set of VAR parameters.

Our interest in conducting such a test lies in our wish to discriminate between very different models' capacities to embrace the dynamic behaviour of the data; in particular New Keynesian models with substantial nominal rigidity as compared with models with flexible prices. We found that the SW model in any form exhibits greatly excessive volatility compared with the data. If this mispecification is dealt with by rescaling to match the data variances, then much depends on the error properties used in the testing process. If one uses SW's assumed error properties (but rescaled) then their model fits the data well, which is consistent with their own findings, but the New Classical version fails. If, however, one uses New Classical priors, which emphasises price flexibility and supply shocks, then the New Classical version passes and SW's New Keynesian model fails. If the actual error properties are assumed then both models have difficulties fitting the data variances. The New Keynesian produces too little variation in nominal variables (especially interest rates) and too much in real variables; in contrast, the New Classical model has too much variation in nominal and too little in real variables. When the two models are artificially combined, and the weight on NC formulation is dominant at over 90%, the combined model passes our tests. This suggests that only some minor modification of the NC to allow for a degree of nominal rigidity is required in order to fit the dynamic facts.

These preliminary explorations in testing a large DSGE model raise two main issues that require further work. First, Smets and Wouters estimated their model using Bayesian methods. This relies on priors about the error distributions, whereas our classical testing procedure is based on solving the model using the observed data. This leads to different conclusions. It would be helpful to gain a better understanding of how the two approaches may be made compatible. Second, even though we have found a version of SW's model that comes quite close to the data, there is still plainly scope for further work to improve model specification.

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Appendix A The Smets-Wouters model

Households

The household utility function is

$$U\left(c_{it}, n_{it}, \frac{M_{it}}{P_t}\right) = \left[\frac{(c_{it} - hc_{it-1})^{1-\sigma_c}}{1-\sigma_c} - \frac{{n_{it}}^{1+\sigma_n}\varepsilon_t^n}{1+\sigma_n} + \frac{\left(\frac{M_{it}}{P_t}\right)^{1-\sigma_m}\varepsilon_t^m}{1-\sigma_m}\right]\varepsilon_t^B$$

where c_{it}, n_{it}, and $\frac{M_{it}}{P_{it}}$ denote the consumption, work and real money balances of the i^{th} household, the ε_t^i, $(i = B, n, m)$ are preference shocks, and P_t is the general price level. The term hc_{t-1} is to capture consumption habits, where c_t is aggregate consumption. The real household budget constraint is

$$\frac{M_{it}}{P_t} + p_t^B\frac{B_{it}}{P_t} = \frac{M_{t-1}}{P_{t-1}} + \frac{B_{i,t-1}}{P_{t-1}} + y_{it} - c_{it} - i_{it}$$

where bonds B_{it} are one-period securities with a price of p_t^B. Total household income is

$$y_{it} = w_{it}n_{it} + a_{it} + r_t^k z_{it}k_{i,t-1} - \Psi(z_{it})\, k_{i,t-1} + d_{it}$$

where w_{it} is the real wage rate, k_{it} is the capital stock, r_t^k is the rate of return to capital, the term $r_t^k z_{it}k_{i,t-1} - \Psi(z_{it})k_{i,t-1}$ represents income from capital after depreciation, z_{it} is capacity utilisation and d_{it} is dividend income.

The resulting Euler equation is

$$E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{R_tP_t}{P_{t+1}}\right] = 1$$

where R_t is the gross nominal rate of return on bonds ($R_t = \frac{1}{p_t^B}$) and λ_t is the marginal utility of consumption:

$$\lambda_t = (c_t - hc_{t-1})^{-\sigma_c}\varepsilon_t^B$$

The demand for money is

$$\left(\frac{M_t}{P_t}\right)^{-\sigma_m}\varepsilon_t^m = (c_t - hc_{t-1})^{-\sigma_c} - \frac{1}{R_t}$$

Households are assumed to act as price setters in the labour market. Their nominal wages are given by

$$W_{it} = \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma} W_{i,t-1}$$

Households set their nominal wages to maximise their inter-temporal objective function subject to their budget constraint and the demand for labour which is given by

$$n_{it} = \left(\frac{W_{it}}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} n_t$$

where n_t the aggregate labour demand and W_t, the aggregate nominal wage, are given by

$$\begin{aligned} n_t &= \left[\int_0^1 (n_{it})^{\frac{1}{1+\lambda_{w,t}}} di\right]^{1+\lambda_{w,t}} \\ W_t &= \left[\int_0^1 (W_{it})^{-\frac{1}{\lambda_{w,t}}} di\right]^{-\lambda_{w,t}} \end{aligned}$$

and

$$\lambda_{w,t} = \lambda_w + \eta_t^w$$

and η_t^w is an *i.i.d.* shock.

The result of this maximisation is the following mark-up equation for the re-optimised wage:

$$\frac{\tilde{w}_t}{P_t} E_t \Sigma_{s=0}^{\infty} \beta^s \xi_w^s \left(\frac{P_t/P_{t-1}}{P_{t+s}/P_{t+s-1}}\right)^{\gamma} \frac{n_{i,t+s} U_{c,t+s}}{1+\lambda_{w,t+s}} = E_t \Sigma_{s=0}^{\infty} \beta^s \xi_w^s n_{i,t+s} U_{n,t+s}$$

where $\tilde{w}_t$ is the new optimal nominal wage, $\xi_w = 0$ if wages are perfectly flexible. The real wage is a mark-up $1 + \lambda_{w,t}$ over the current ratio of the marginal disutility of labour to the marginal utility of an additional unit of consumption. As a result, the aggregate wage satisfies

$$W_t^{-\frac{1}{\lambda_w}} = \xi \left[W_{t-1} \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma}\right]^{-\frac{1}{\lambda_w}} + (1-\xi) \tilde{w}_t^{-\frac{1}{\lambda_w}}$$

Households, who own firms, choose the capital stock and investment to maximise their inter-temporal subject to their budget constraint and the capital accumulation condition

$$k_t = (1-\delta) k_{t-1} + I\left(\frac{i_t \varepsilon_t^i}{i_{t-1}}\right) i_t$$

where $I(\frac{i_t \varepsilon_t^i}{i_{t-1}})$ is an adjustment cost function, and ε_t^i is an investment shock determined by the autoregression

$$\varepsilon_t^i = \rho \varepsilon_{t-1}^i + \eta_t^i$$

The first-order conditions are

$$\begin{aligned}
Q_t &= E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\left[Q_{t+1}(1-\delta)+z_{t+1}r^k_{t+1}-\Psi(z_{t+1})\right]\right] \\
1 &= Q_t I'\left(\frac{i_t\varepsilon^i_t}{i_{t-1}}\right)\left(\frac{i_t\varepsilon^i_t}{i_{t-1}}\right)+\beta E_t Q_{t+1}\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{i_{t+1}\varepsilon^i_{t+1}}{i_t}\right)\left(\frac{i_{t+1}\varepsilon^i_{t+1}}{i_t}\right)\left(\frac{i_{t+1}}{i_t}\right) \\
r^k_{t+1} &= \Psi'(z_t)
\end{aligned}$$

where Q_t is the value of installed capital.

Firms

It is assumed that there is a single final competitive good and a continuum of monopolistically produced intermediate goods indexed by j, where j is distributed over the unit interval ($j \in [0,1]$). The final good is produced by

$$y_t = \left[\int_0^1 y_t^{j\,\frac{1}{1+\lambda_{p,t}}}\,dj\right]^{1+\lambda_{p,t}}$$

where y_t^j is the intermediate good and ν_t is a mark-up generated by

$$\lambda_{p,t} = \lambda_p + \eta_t^p$$

where η_t^p is an *i.i.d.* shock. Cost minimisation gives the demand function for intermediate goods as

$$y_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\frac{1+\lambda_{p,t}}{\lambda_{p,t}}} y_t$$

and the final goods price level which is

$$P_t = \left[\int_0^1 (p_{jt})^{-\frac{1}{\lambda_{p,t}}}\,dj\right]^{-\lambda_{p,t}}$$

where p_{jt} are the prices of intermediate goods.

Intermediate goods are produced using the technology

$$y_{jt} = (z_t k_{j,t-1})^{\alpha} N_{j,t}^{1-\alpha}\varepsilon^a_t - \Phi$$

where $N_{j,t}$ is an index of different types of labour used by firms, Φ is a fixed cost and ε^a_t is the productivity shock. Cost minimisation implies that

$$\frac{W_t N_{j,t}}{r^k_t z_t k_{j,t-1}} = \frac{1-\alpha}{\alpha}$$

The firm's marginal cost is

$$MC_t = \frac{1}{\varepsilon_t^a} W_t^{1-\alpha} \left(r_t^k\right)^a \left[\alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\right]$$

which is independent of the intermediate good produced. Nominal firm profits are

$$\pi_{j,t} = (p_{jt} - MC_t)\left(\frac{p_{jt}}{P_t}\right)^{-\frac{1+\lambda_{p,t}}{\lambda_{p,t}}} y_t - MC_t\Phi$$

Firms are assumed to be able to re-optimise their price randomly with probability $1-\xi_p$ as in the Calvo model. The optimal price $\tilde{p}_t$ is obtained from the first-order condition

$$E_t\Sigma_{s=0}^{\infty}\beta^s\xi_p^s\lambda_{t+s}y_{j,t+s}\left[\frac{\tilde{p}_t}{P_t}\left(\frac{P_{t+s-1}/P_{t-1}}{P_{t+s}/P_t}\right)^{\gamma} - (1+\lambda_{p,t+s})\frac{MC_{t+s}}{P_{t+s}}\right] = 0$$

which shows that the optimal price is a function of future marginal costs, and is a mark-up over them unless $\lambda_p = 0$. The general price index therefore satisfies

$$P_t^{-\frac{1}{\lambda_{p,t}}} = \xi_p\left(P_{t-1}(\frac{P_{t-1}}{P_{t-2}})^{\lambda_p}\right)^{-\frac{1}{\lambda_{p,t}}} + (1-\xi_p)\tilde{p}_t^{-\frac{1}{\lambda_{p,t}}}$$

Market equilibrium

Final goods market equilibrium satisfies the national income constraint

$$y_t = c_t + i_t + g_t + \Psi(z_t)k_{t-1}$$

Solution

We solve the model in its non-linear form above with DYNARE which uses a second-order Taylor series approximation to the model. The errors named in the text are given as follows

ϵ_t^B = Preference Shock	η_t^n = Labour Preference Shock
ϵ_t^i = Investment Shock	η_t^w = Wage Mark-up Shock
η_t^Q = Equity Shock	ϵ_t^g = Government Spending Shock
ϵ_t^a = Productivity Shock	$\bar{\pi}_t$ = Inflation Objective Shock
η_t^p = Price Mark-up Shock	η_t^R = Monetary Shock

Log-linearised model

For the empirical analysis by SW the model is log-linearised around its non-stochastic steady-state. Denoting log-deviations about equilibrium by a caret ˆ, and noting that variables dated $t+1$ are rational expectations, the log-linearised model is

$$
\begin{aligned}
\hat{c}_t &= \frac{h}{1+h}\hat{c}_{t-1} + \frac{1}{1+h}\hat{c}_{t+1} - \frac{1-h}{(1+h)\sigma_c}\left[\left(\hat{R}_t - \hat{\pi}_{t+1}\right) + \left(\hat{\varepsilon}_t^b - \hat{\varepsilon}_{t+1}^b\right)\right] \\
\hat{\imath}_t &= \frac{1}{1+\beta}\hat{\imath}_{t-1} + \frac{\beta}{1+\beta}\hat{\imath}_{t+1} + \frac{\varphi}{1+\beta}\hat{Q}_t + \beta\hat{\varepsilon}_t^i - \hat{\varepsilon}_t^i \\
\hat{Q}_t &= -\left(\hat{R}_t - \hat{\pi}_{t+1}\right) + \frac{1-\delta}{1-\delta+\bar{r}^k}\hat{Q}_{t+1} + \frac{\bar{r}^k}{1-\delta+\bar{r}^k}\hat{r}_t^k + \hat{\eta}_t^Q \\
\hat{\pi}_t &= \frac{\nu}{1+\beta\gamma_p}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta\gamma_p}\hat{\pi}_{t+1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{(1+\beta\gamma_p)\xi_p}\left[\alpha\hat{r}_t^k + (1-\alpha)\hat{w}_t - \hat{\varepsilon}_t^a + \eta_t^p\right] \\
\hat{w}_t &= \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}\hat{w}_{t+1} + \frac{\gamma_w}{1+\beta}\hat{\pi}_{t-1} - \frac{1+\beta\gamma_w}{1+\beta}\hat{\pi}_t + \frac{\beta}{1+\beta}\hat{\pi}_{t+1} \\
&\quad - \frac{(1-\beta\xi_w)(1-\xi_w)}{(1+\beta)\left[1+\frac{(1+\lambda_w)\sigma_n}{\lambda_w}\right]\xi_w}\left[\hat{w}_t - \sigma_n\hat{N}_t - \frac{\sigma_c}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) - \hat{\varepsilon}_t^n - \eta_t^w\right] \\
\hat{N}_t &= -\hat{w}_t + (1+\Psi)\hat{r}_t^k + \hat{k}_{t-1} \\
\hat{y}_t &= (1-\delta k_y - g_y)\hat{c}_t + \delta k_y\hat{\imath}_t + g_y\hat{\varepsilon}_t^g = \phi[\hat{\varepsilon}_t^g + \alpha\hat{k}_{t-1} + \alpha\psi\hat{r}_t^k + (1-\alpha)\hat{N}_t \\
\hat{R}_t &= \rho\hat{R}_{t-1} + (1-\rho)\left[\bar{\pi}_t + r_\pi\left(\hat{\pi}_{t-1} - \bar{\pi}_t\right) + r_y\hat{y}_t\right] + r_{\Delta\pi}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + r_{\Delta y}\left(\hat{y}_t - \hat{y}_{t-1}\right) \\
&\quad - r_a\eta_t^a - r_n\eta_t^n + \eta_t^R
\end{aligned}
$$

where $\varphi = I''^{-1}$, $\beta = (1-\delta+\bar{r}^k)^{-1}$, $\psi = \frac{\Psi'(1)}{\Psi''(1)}$, $\bar{\pi}_t$ is the inflation target and the equations include various parameters which are long-run average values. Thus, there are nine endogenous variables and ten independent shocks. Five of the shocks arise from technology and preferences $(\varepsilon_t^a, \varepsilon_t^i, \varepsilon_t^b, \varepsilon_t^n, \varepsilon_t^g)$ which are generated by first-order autogressive processes, three are cost-push shocks $(\eta_t^w, \eta_t^p, \eta_t^Q)$ which are *i.i.d.* shocks and two are monetary shocks $(\bar{\pi}_t,\ \eta_t^R)$.

Appendix B The Wald Statistic and the Variance-Covariance matrix W

In evaluating the model's overall performance via the Wald statistic, we need to compute the W, variance-covariance matrix. In this the diagonal, the variances, creates no problem; plainly the VAR coefficients have a sampling variation and the best estimate of the variance is given by the variance of this bootstrap sampling distribution. However, the covariances are another matter.

First, we may note that the role of these parameter covariances turns out to be important. We find in the exercise we are carrying out here that the Wald statistics depend greatly on whether we assume the VAR parameter covariances are zero or not. All our model versions turn out to have a Wald statistic of 100 (outright rejection) when the covariances are given by the bootstrap sample variation; whereas when the covariances are constrained to zero the Wald statistics come down below the 100 mark to varying degrees. To understand what is at stake we may think of a VAR with just two parameters, for example inflation and interest rates regressed only on their own individual past (a diagonalised VAR). Suppose that the model distribution is centred around 0.5, and 0.5; and the data-based VAR produced values for their partial autocorrelations of 0.1 and 0.9 respectively for inflation and interest rates — the two VAR coefficients. Suppose too that the 95% range for each was 0–1.0 (a standard deviation of 0.25) and thus each is accepted individually. If the parameters are uncorrelated across samples, then the situation is as illustrated in the 3-D diagram below. The height of the diagram shows the density of parameter combinations across the samples. Here the mean of each parameter's distribution remains constant regardless of the value of the other parameter. Of course the joint parameter combination will also be accepted because of this independence.

Now consider the case where there is a high positive covariance between the parameter estimates across samples. Thus suppose that in samples with high inflation autocorrelation we also find high interest rate autocorrelation (because of the Fisher effect perhaps). For example Figure 6 illustrates the case for a 0.9 cross-correlation between the two parameters. The effect of the high covariance is to create a 'ridge' out of the 'density mountain'. Hence at high values of the interest rate autocorrelation the mean of the inflation autocorrelation is now increased from 0.5; for example at an interest rate parameter of 0.9 the mean of the inflation parameter distribution will be 0.86; the distance of 0.1 from a mean of 0.86 is 3.04 standard deviations. Thus the joint parameter combination of 0.1,0.9 will be rejected even though individually the two parameters are accepted.

One can also get the opposite effect: that two parameters are individually outside their 95% bounds but a high covariance places them on the ridge within the 95% joint bound. In the distributions shown, an example would be where both parameters were -0.01, just outside their individual 95% bounds. With a 0.9 cross-correlation between them, they would be jointly accepted, as can clearly be seen on the figure.

When there are numerous VAR parameters, each pair will have the characteristics just described, creating ridges in multiple dimensions.

Thus the covariances are of some importance. The question is how far we believe evidence from samples that such parameters as partial correlations (such as VAR parameters) vary systematically with the values of other partial correlations. We impose for example, on time-series models and on our VAR model in particular, the property of homoscedasticity, whereby the coefficients have a constant variance within each sample — as opposed to some ARCH model. We could also impose on our VAR the property that the parameter estimates vary across different samples, but that this variation does not covary with other parameter estimates. Thus we would be saying that any apparent covariation is occurring randomly- just as any apparent heteroscedasticity within a sample would be treated as random under the homoscedasticity assumption. We would be specifying the VAR in a certain way in capturing the properties of the data, in thus imposing zero covariances (constant means).

Thus the hypothesis that the covariances are zero is one we could reasonably entertain. It is difficult to test, because our direct estimate of the covariances, based on the assumption that they are non-zero, uses all the bootstraps and is tightly defined for a large number of bootstraps. For example if we redo the 1000 bootstraps 100 times, we find that there is not much variation in the estimates: essentially the 1000 bootstraps generate similar variations in VAR parameters across the 1000 samples each time. We can however appeal to the existence of alternative estimates of the covariances. There are two we could use: those from the mean of the bootstrap sample covariances and those from a VAR on the actual data. Under the structural model null these are all valid estimates of the true covariance. A test we could use would be to ask whether the range of these estimates includes zero. We find that for the three cases that pass our tests, the vast majority of the covariances have zero within this range or within 0.001 of it. Thus for the SW model using its own error assumptions 69% lie within this range, 91% lie within 0.001 of it and 99% lie within 0.01 of it. For the New Classical using its own error assumptions the figures are 45%, 80% and 96%. For the weighted average model they are 33%, 79% and 95%. Of course this implies that many of the covariances are distributed on either side of zero so that one cannot even be sure of their sign. Since a wrong sign can cause rejection, this is a serious danger. In these circumstances we decided to use the diagonalised variance-covariance matrix to give our Wald statistic. We also report- for our three main cases- another estimate of the Wald statistic that is very similar: where the covariances are taken from the VAR on the actual data (estimated by bootstrapping to obtain the small sample value). It is similar because the covariances estimated on the actual data are close to zero.

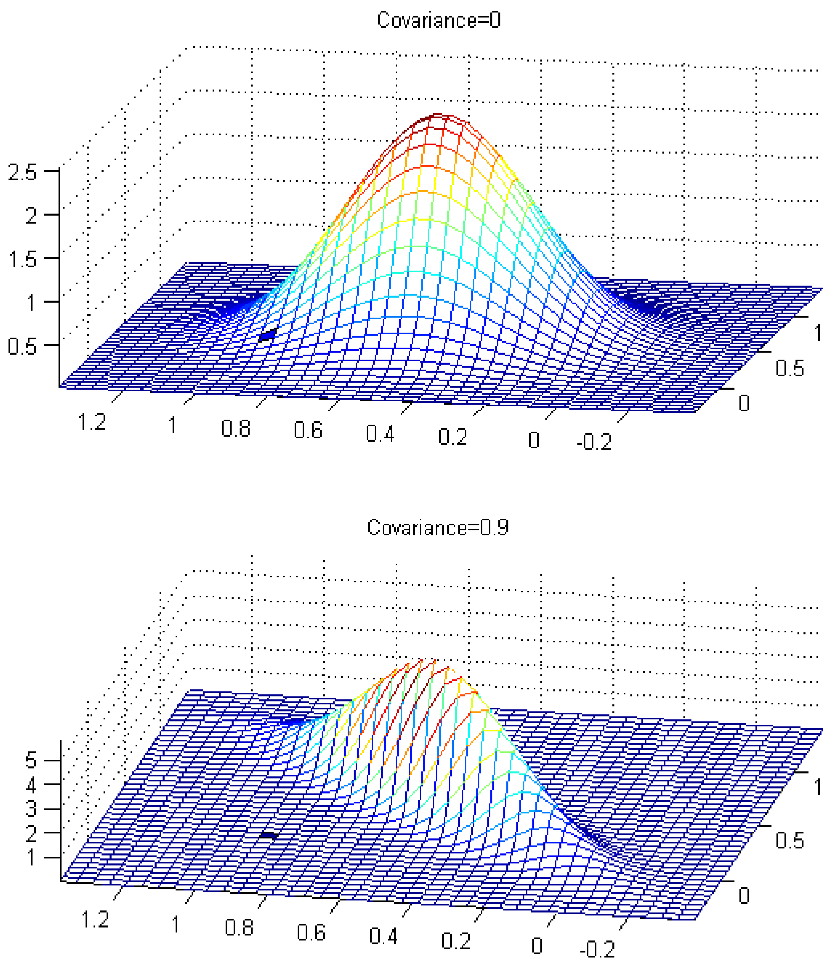

Figure 6: Bivariate Normal Distributions (0.1, 0.9 shaded)

Appendix C SW's Model (ρs as set by SW, matching SW variances of innovations) — scaling 0.3 times all shocks

C.1 Randomly selected Bootstraps versus Actual Data

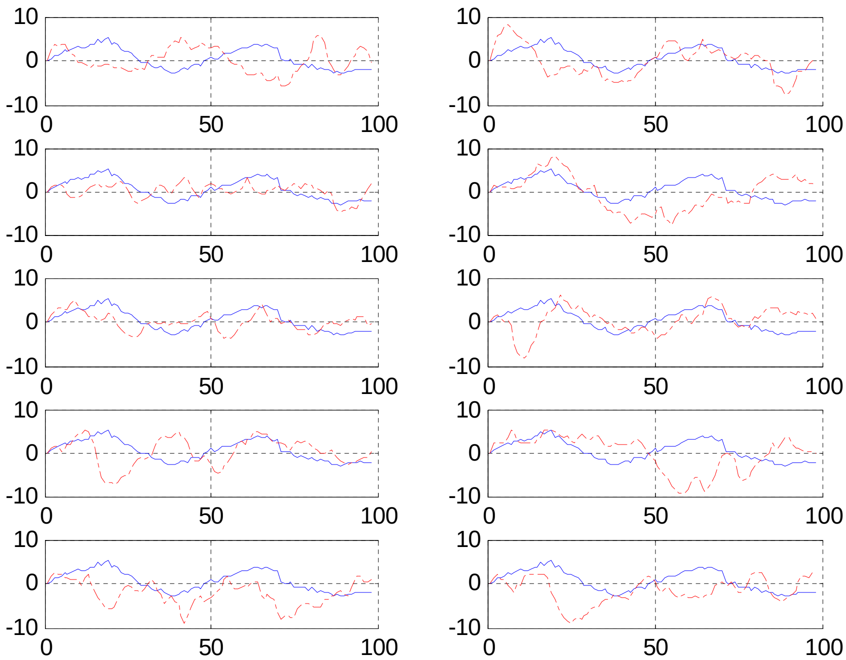

Figure 7: Consumption (Actual=blue, Simulated=red)

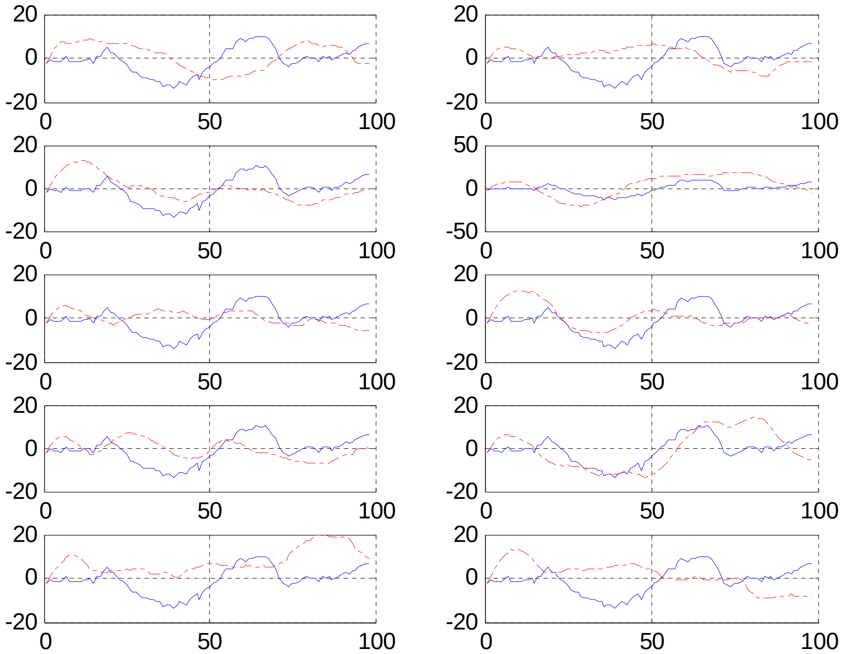

Figure 8: Investment (Actual=blue, Simulated=red)

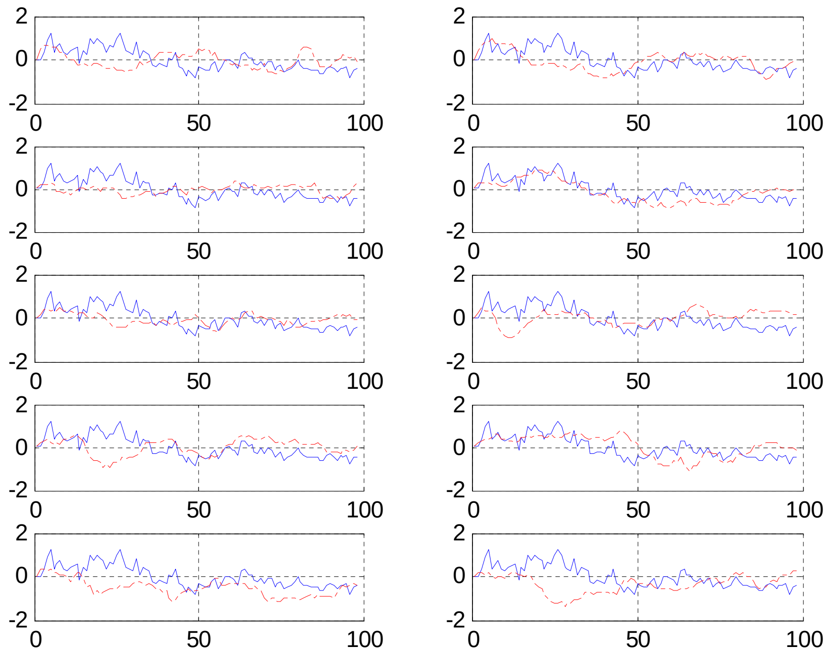

Figure 9: Inflation (Actual=blue, Simulated=red)

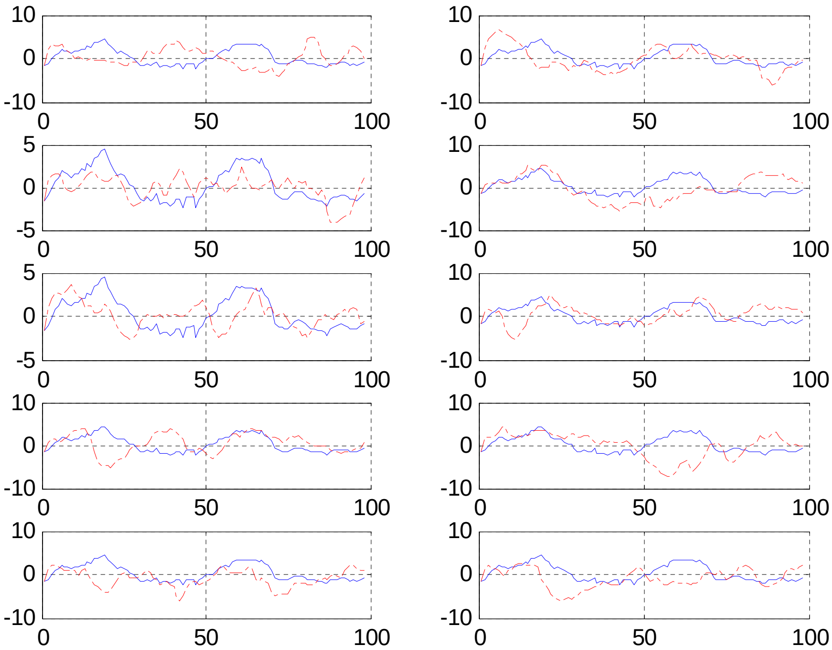

Figure 10: Output (Actual=blue, Simulated=red)

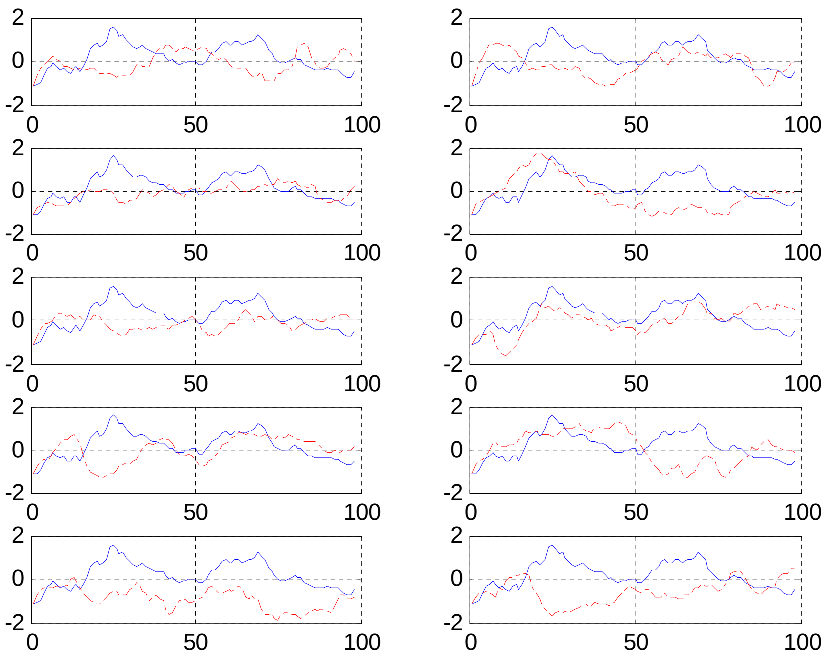

Figure 11: Interest Rate (Actual=blue, Simulated=red)

C.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

The red dotted lines denotes the upper and the lower bounds of the distribution of the IRF and the blue solid one is the IRF of the actual data.

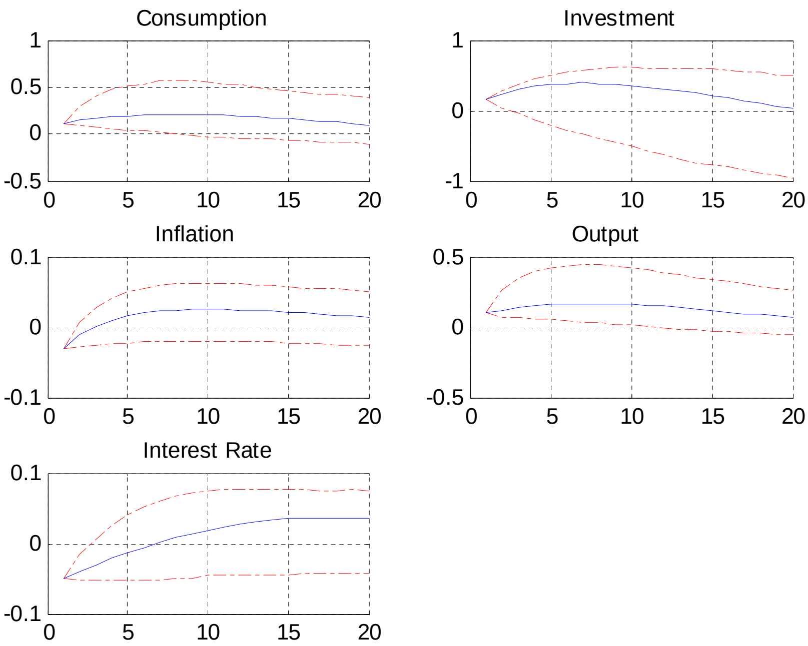

Figure 12: Productivity Shock

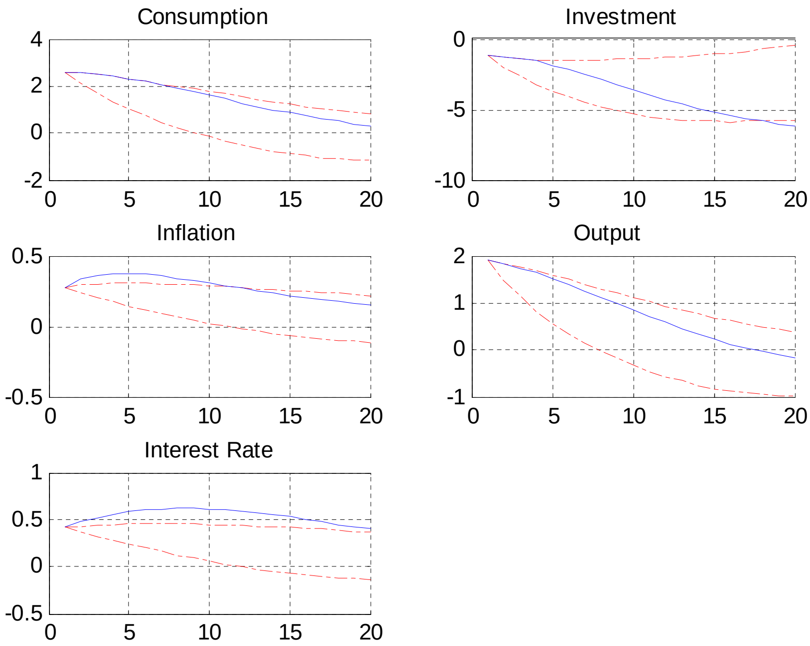

Figure 13: Consumer Preference Shock

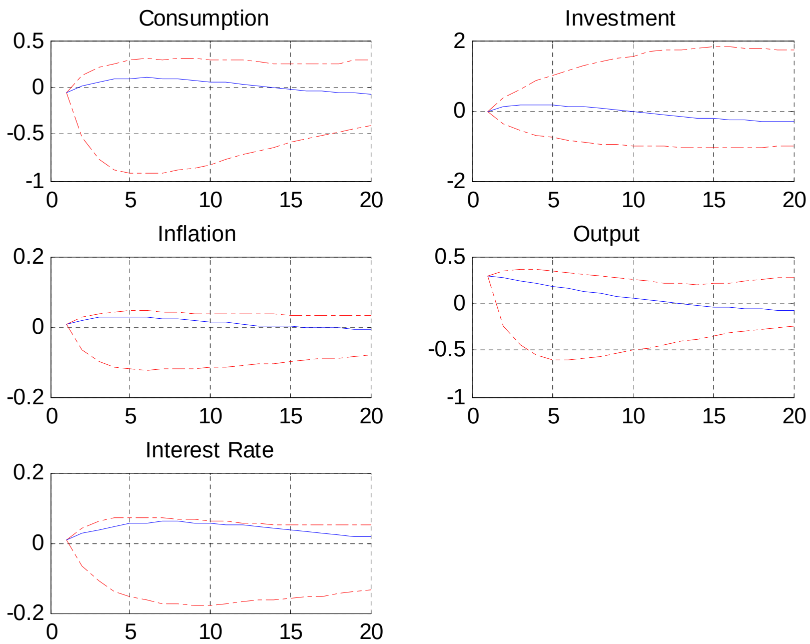

Figure 14: Government Spending Shock

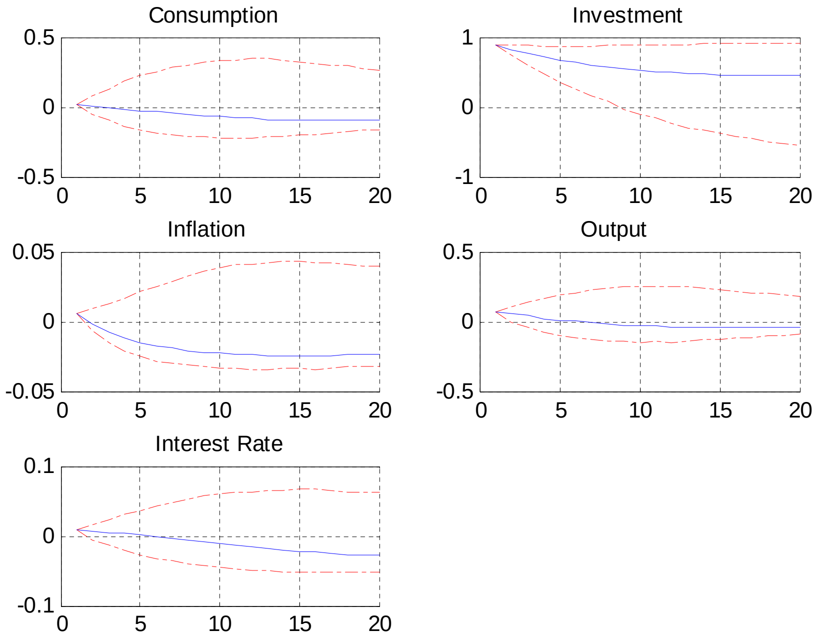

Figure 15: Investment Shock

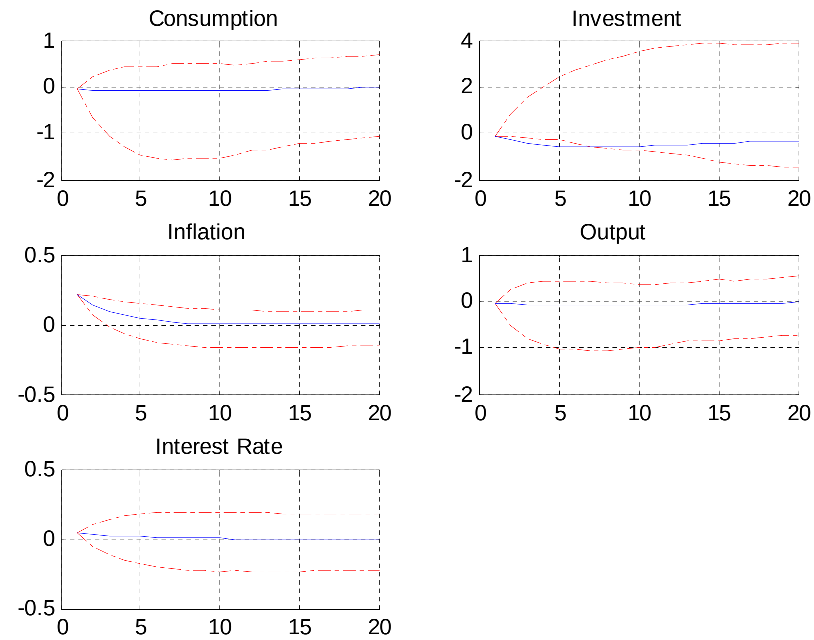

Figure 16: Price Shock

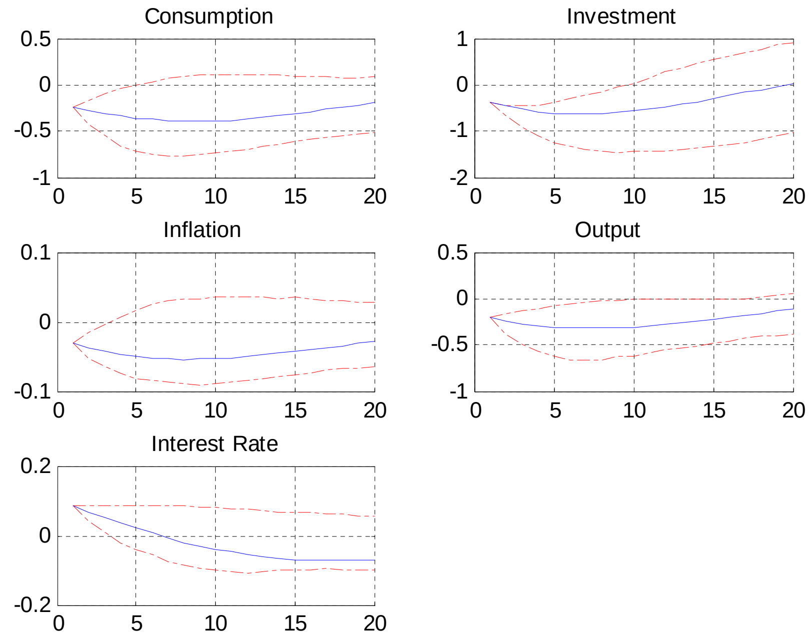

Figure 17: Monetary Shock

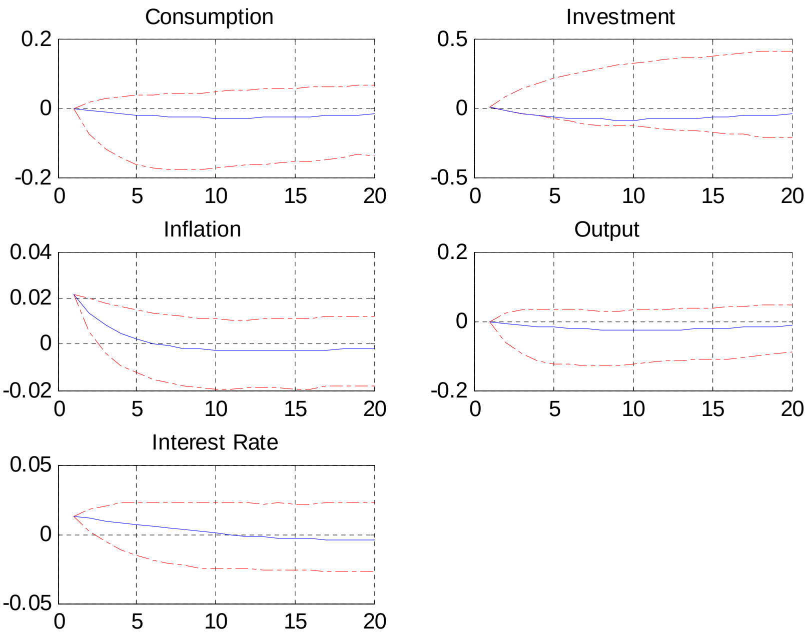

Figure 18: Wage Shock

C.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.67784	2.17487	TRUE	-1.29699
A_C^I	-0.09612	-1.01321	0.71139	TRUE	0.13541
A_C^π	0.01867	-0.02040	0.20112	TRUE	-1.18651
A_C^Y	0.07935	-0.06675	1.26126	TRUE	-1.43262
A_C^R	-0.00824	-0.05480	0.19518	TRUE	-1.24489
A_I^C	-0.02461	-0.08517	0.12605	TRUE	-0.89331
A_I^I	0.91856	0.80536	1.04445	TRUE	-0.22981
A_I^π	-0.01074	-0.01390	0.01436	TRUE	-1.61228
A_I^Y	-0.01190	-0.06222	0.11812	TRUE	-0.83873
A_I^R	-0.00504	-0.01477	0.01963	TRUE	-0.85038
A_π^C	-0.04105	-2.75549	1.36838	TRUE	0.58582
A_π^I	-0.71538	0.00212	4.65028	FALSE	-2.81450
A_π^π	0.68194	0.33816	0.94001	TRUE	0.05555
A_π^Y	-0.00692	-2.00221	1.50416	TRUE	0.27295
A_π^R	-0.01605	-0.37265	0.34662	TRUE	-0.00606
A_Y^C	0.21989	-1.42637	0.58019	TRUE	1.21983
A_Y^I	0.38855	-1.10769	1.14039	TRUE	0.64902
A_Y^π	0.05457	-0.20815	0.08309	TRUE	1.54982
A_Y^Y	0.93795	-0.55498	1.18992	TRUE	1.32594
A_Y^R	0.06281	-0.22013	0.11210	TRUE	1.43788
A_R^C	-0.37666	-1.83366	0.58254	TRUE	0.40611
A_R^I	-0.97612	-3.20523	-0.88981	TRUE	1.76556
A_R^π	-0.05704	-0.22694	0.09598	TRUE	-0.04928
A_R^Y	-0.40669	-1.84650	0.09677	TRUE	0.85200
A_R^R	0.89695	0.60858	0.98785	TRUE	0.91781
	Wald Statistic	75.7			

*t-stat from bootstrap mean

Table 15: VAR Parameters & Model Bootstrap Bounds (SW model with SW rhos and variances of innovations)

C.4 Results for SW's Model (ρs as set by SW, matching SW variances)

	Prod	Cons	Gov	Inv	Price	Int	Wage
ρ	0.828	0.886	0.956	0.917	0	0	0
Var	0.375	0.088	0.108	0.017	0.026	0.017	0.081

Table 16: AR Coefficients and Variances of Shocks for SW's Model with SW rhos and variances of innovations

	Full varcovar	Just variances	Direct vars/Actual covars
VAR(1)	100	75.7	75.7

Table 17: Wald Statistics for SW's Model with SW rhos and variances of innovations

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	3.2602	10.5080	0.0453	1.8286	0.1013
Upper	16.4491	101.1404	0.2578	8.6823	0.5723
Mean	7.8083	40.1094	0.1164	4.3093	0.2565

Table 18: Variance of Data and Bootstraps for SW's Model with SW rhos and variances of innovations

	Prod	Cons	Gov	Inv	Price	Int	Wage	TOTAL
C	0.561	95.276	0.293	2.577	0.092	1.173	0.027	100
I	0.622	79.123	0.036	18.336	0.161	1.689	0.034	100
K	0.499	80.629	0.054	17.609	0.098	1.084	0.028	100
L	3.472	91.455	1.435	2.028	0.105	1.454	0.051	100
π	0.295	95.017	0.033	0.310	3.285	0.880	0.181	100
Q	1.059	51.598	0.007	38.638	0.632	7.973	0.093	100
R	0.447	98.729	0.042	0.325	0.070	0.365	0.021	100
rk	0.546	90.329	0.221	7.749	0.143	0.800	0.212	100
W	0.638	86.600	0.066	7.464	0.699	2.445	2.088	100
Y	0.891	90.848	1.139	4.976	0.159	1.943	0.044	100

Table 19: Variance Decomposition for SW's Model with SW rhos and variances of innovations

C.5 Cross-Correlations for SW's Model (ρs as set by SW, matching SW variances)

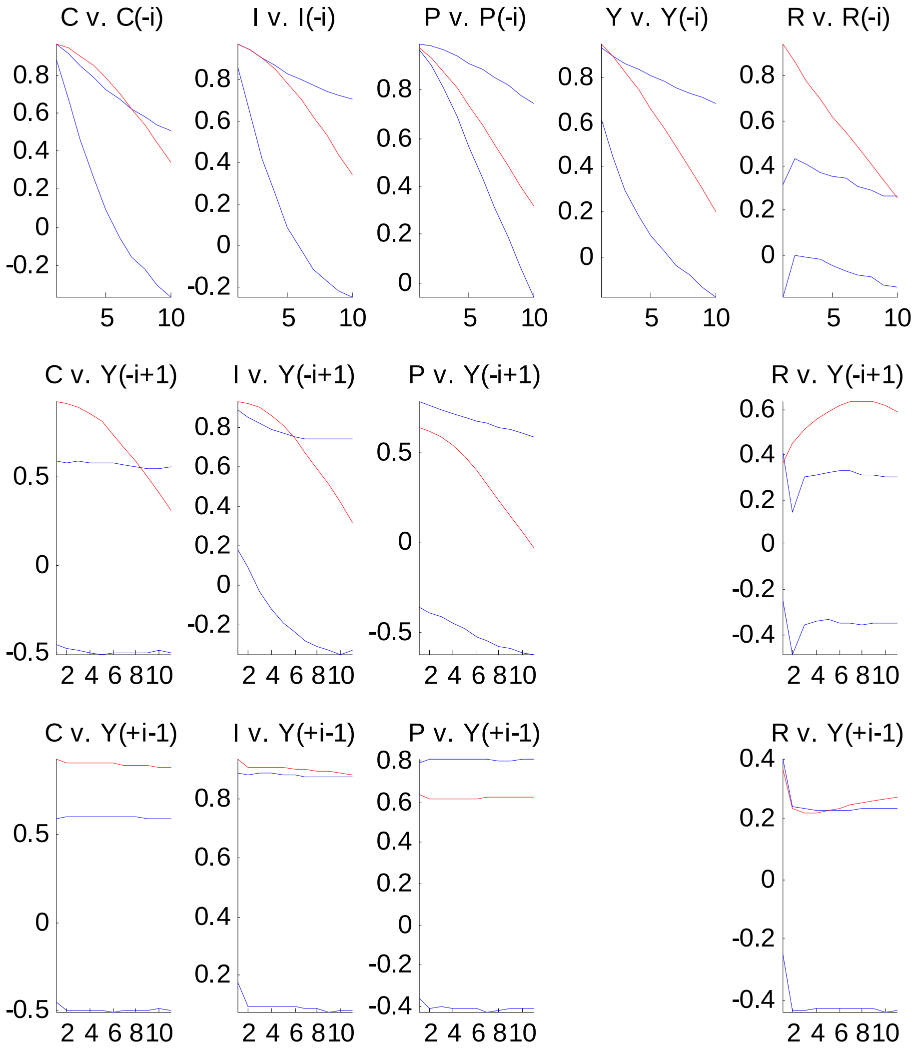

Figure 19: Cross-Correlations for SW's Model with SW rhos

Appendix D Comparison of Dynare Solution IRFs with SW

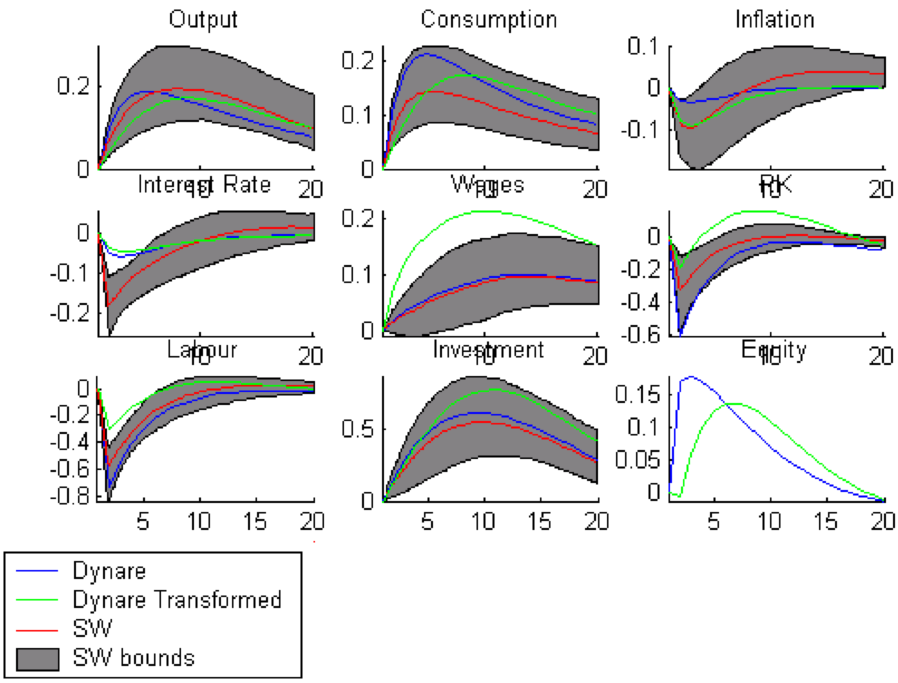

Figure 20: **Productivity Shock** [DYNARE (1st order approximation) and actual SW as they appear in their paper]

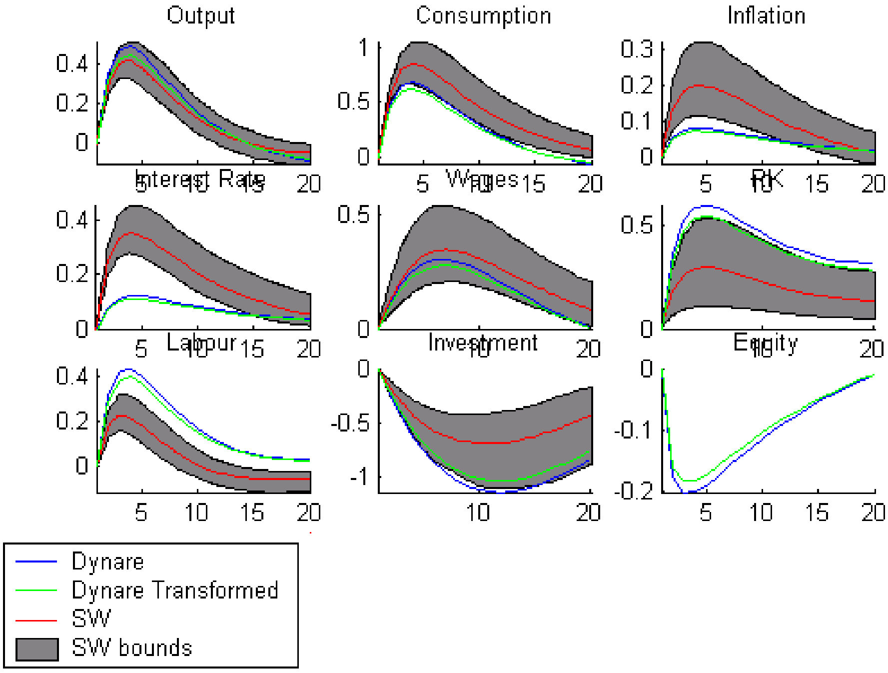

Figure 21: **Consumption Preference** [DYNARE (1st order approximation (a)direct approximation; (b) after transformation to VAR form) and actual SW as they appear in their paper]

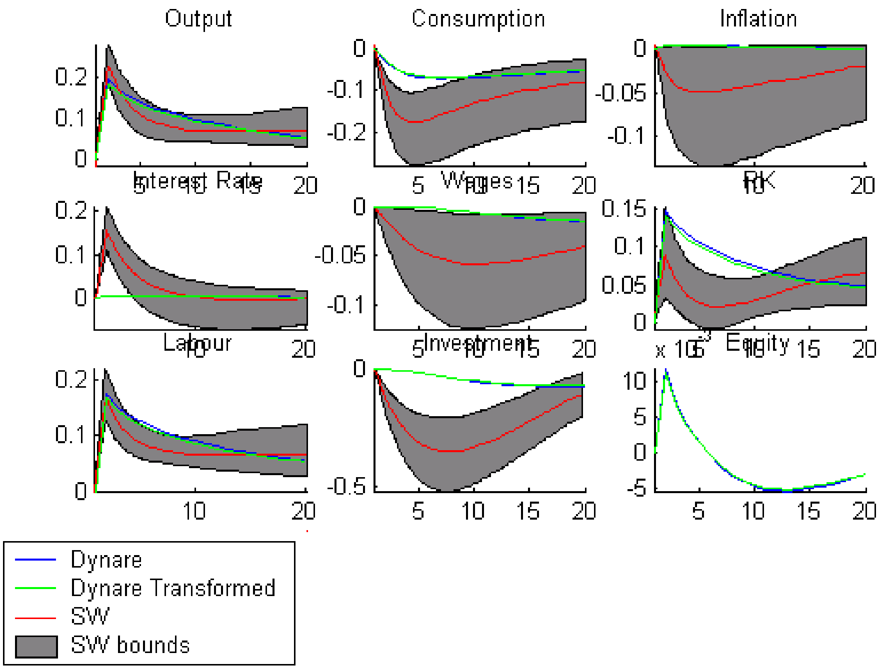

Figure 22: **Government Spending** [DYNARE (1st order approximation (a)direct approximation; (b) after transformation to VAR form) and actual SW as they appear in their paper]

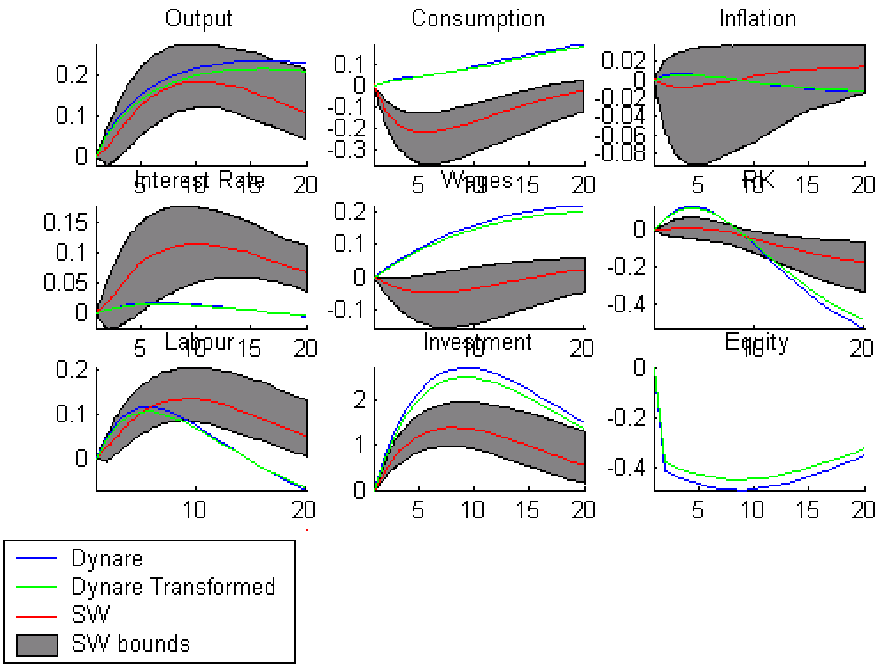

Figure 23: **Investment** [DYNARE (1st order approximation (a)direct approximation; (b) after transformation to VAR form) and actual SW as they appear in their paper]

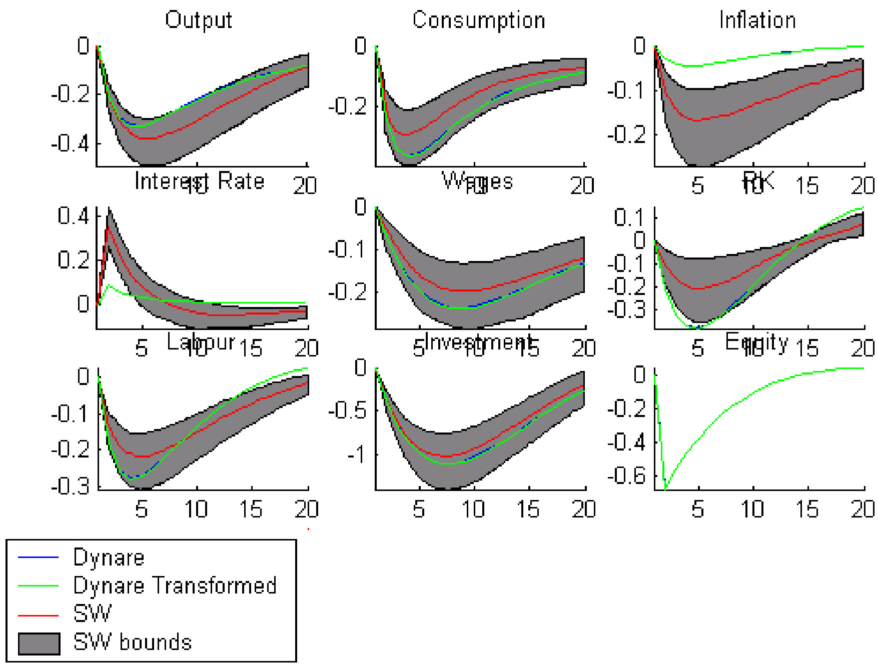

Figure 24: **Monetary** [DYNARE (1st order approximation (a)direct approximation; (b) after transformation to VAR form) and actual SW as they appear in their paper]

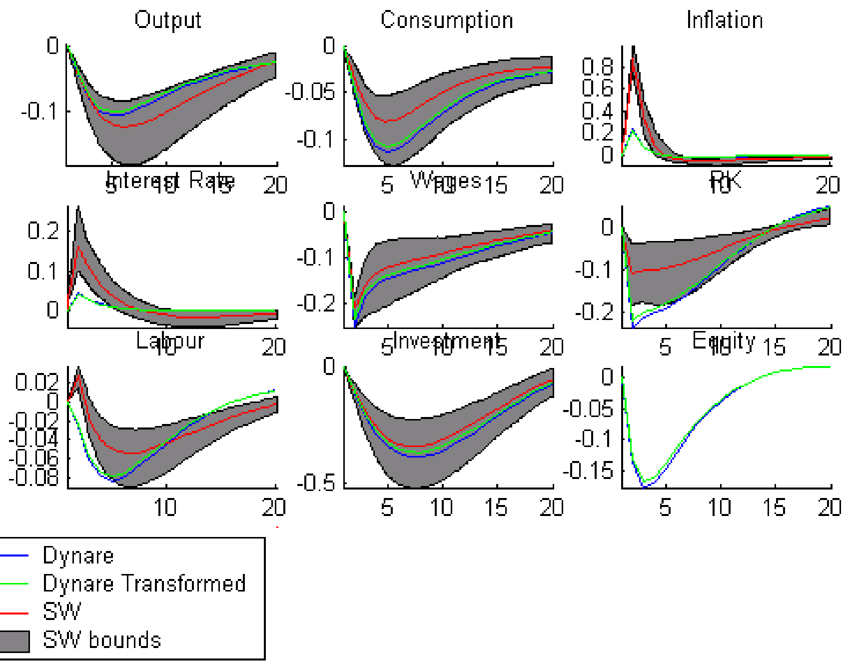

Figure 25: **Price Mark-up** [DYNARE (1st order approximation (a)direct approximation; (b) after transformation to VAR form) and actual SW as they appear in their paper]

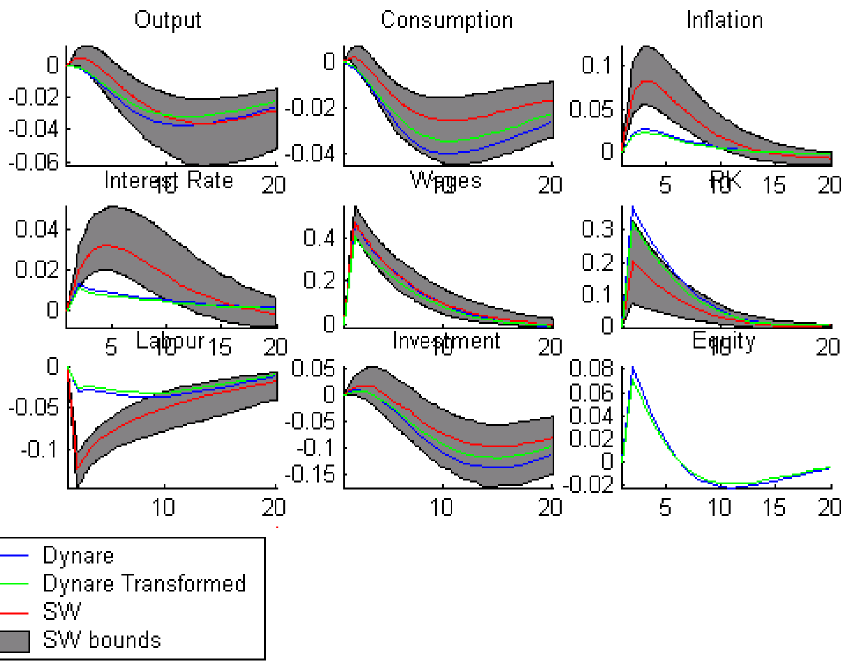

Figure 26: **Wage Mark-up** [DYNARE (1st order approximation (a)direct approximation; (b) after transformation to VAR form) and actual SW as they appear in their paper]

Appendix E Flexprice Version of the Model (ρs as set by SW, matching SW variances of innovations) — scaling 0.8 times all shocks

E.1 Randomly selected Bootstraps versus Actual Data

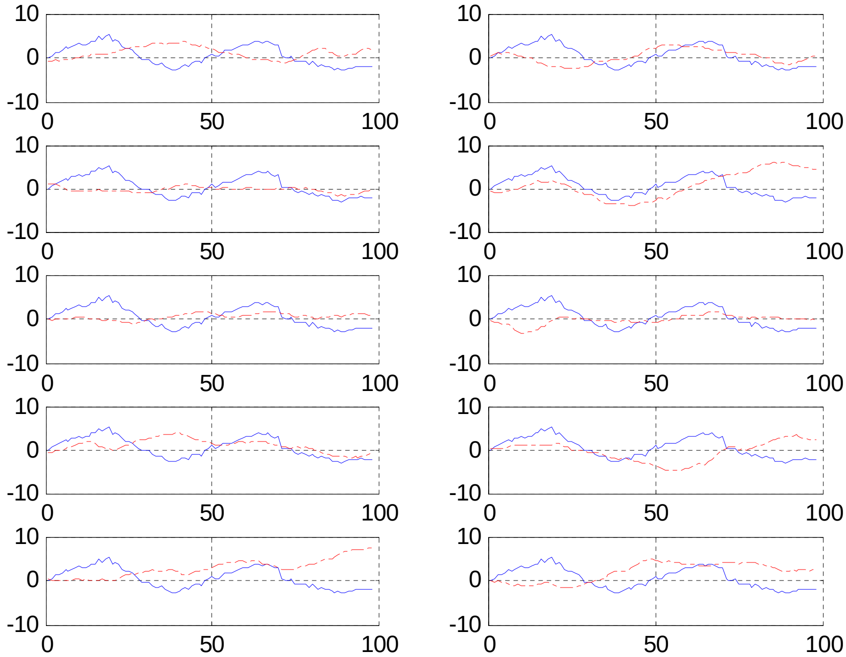

Figure 27: Consumption (Actual=blue, Simulated=red)

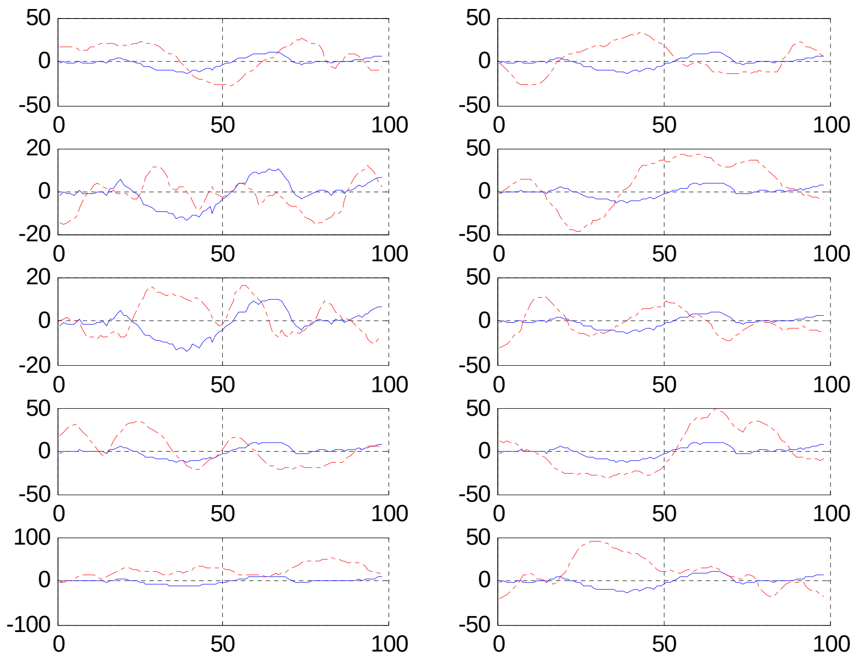

Figure 28: Investment (Actual=blue, Simulated=red)

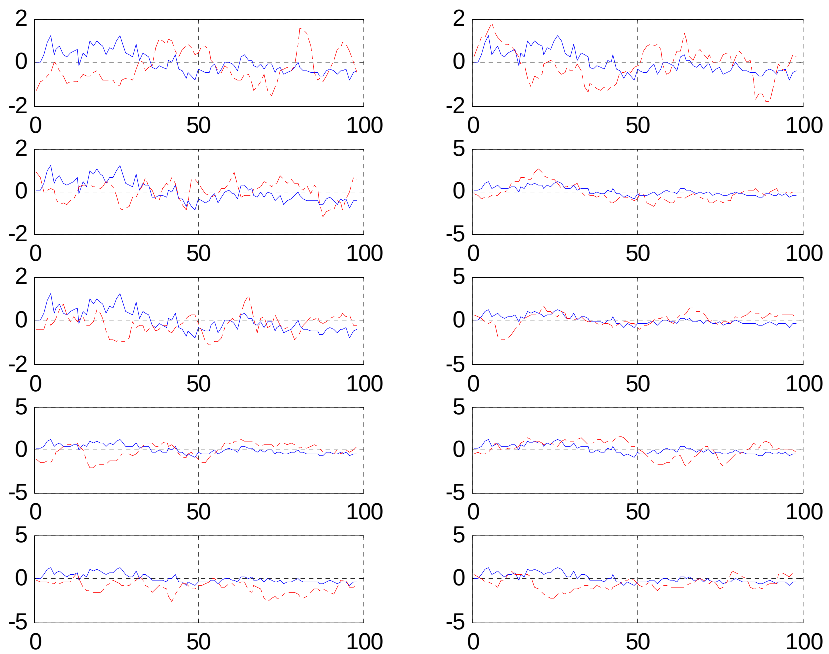

Figure 29: Inflation (Actual=blue, Simulated=red)

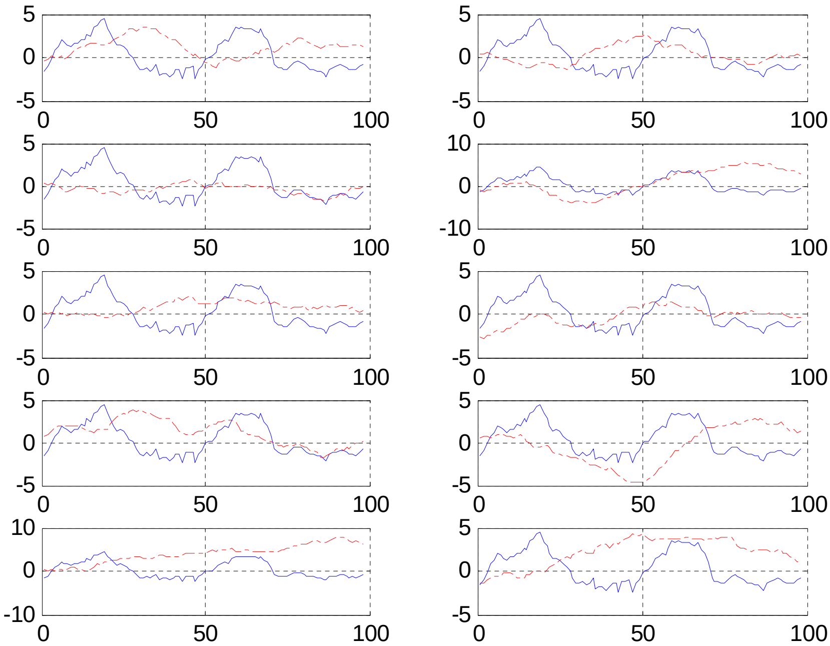

Figure 30: Output (Actual=blue, Simulated=red)

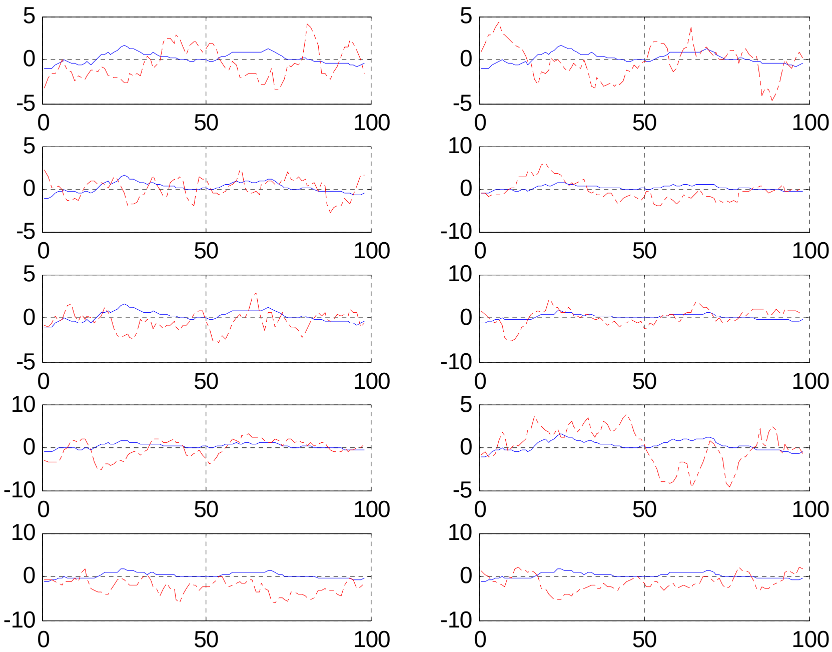

Figure 31: Interest Rate (Actual=blue, Simulated=red)

E.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

The red dotted lines denotes the upper and the lower bounds of the distribution of the IRF and the blue solid one is the IRF of the actual data.

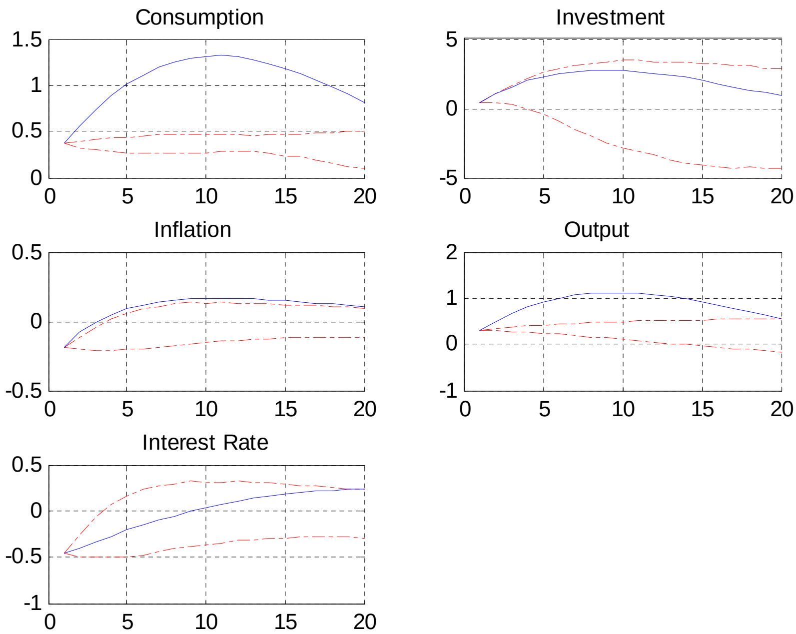

Figure 32: Productivity Shock

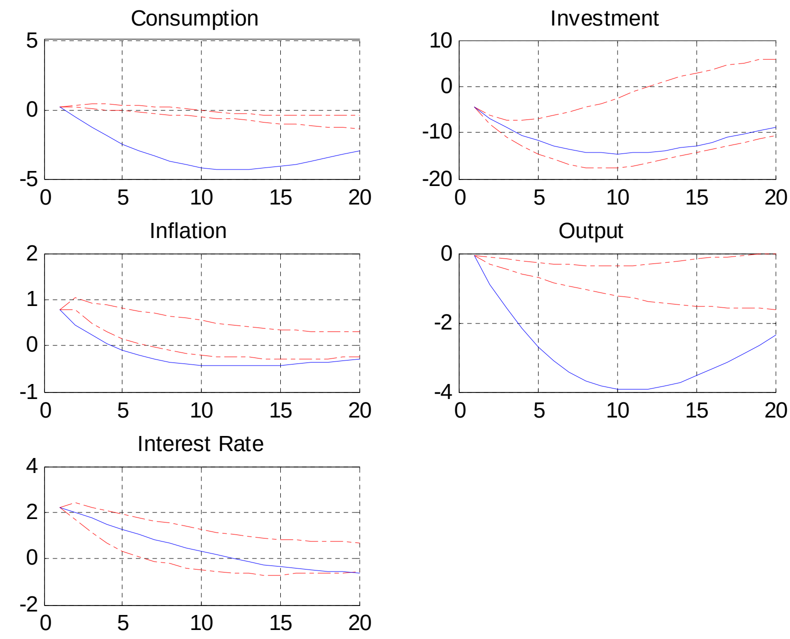

Figure 33: Consumer Preference Shock

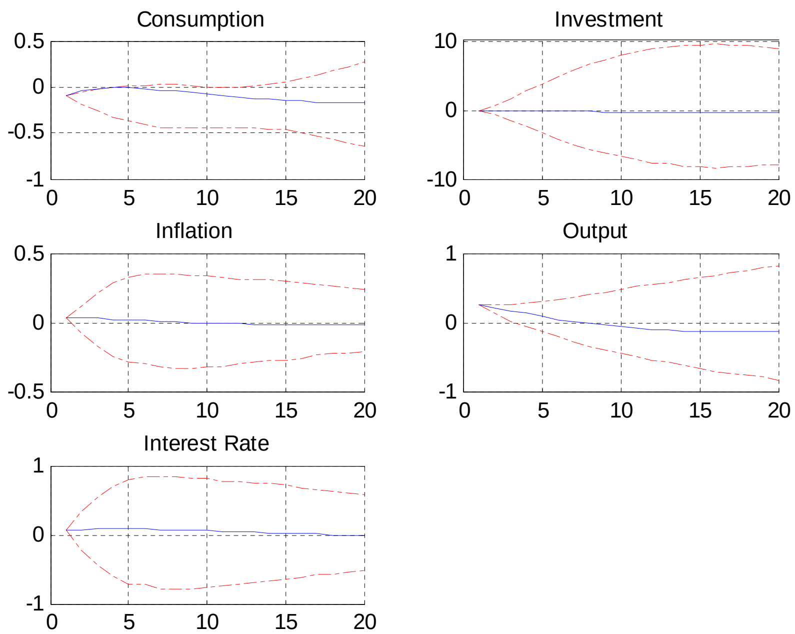

Figure 34: Government Spending Shock

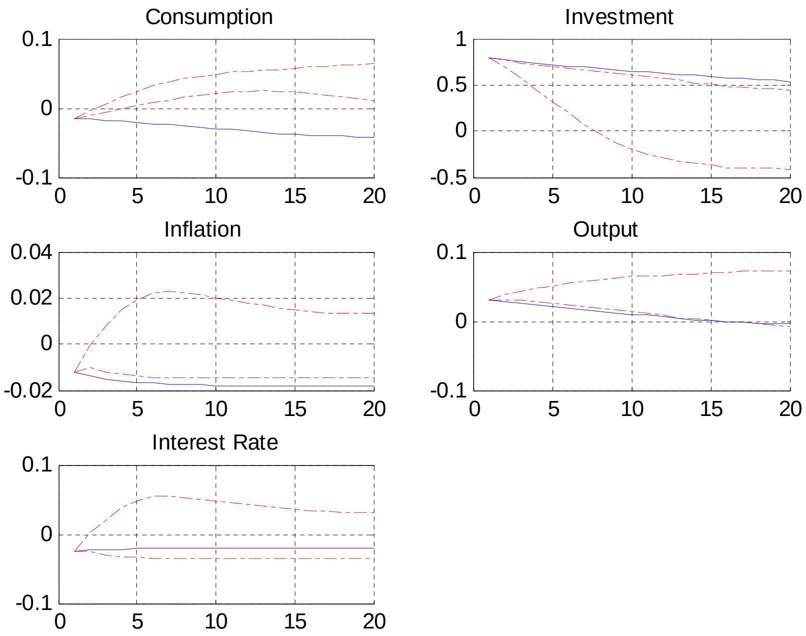

Figure 35: Investment Shock

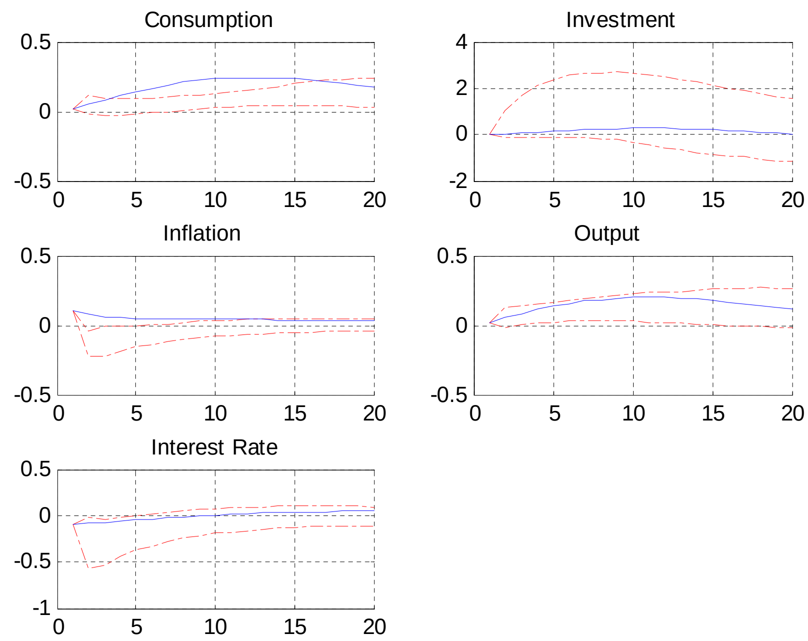

Figure 36: Price Shock

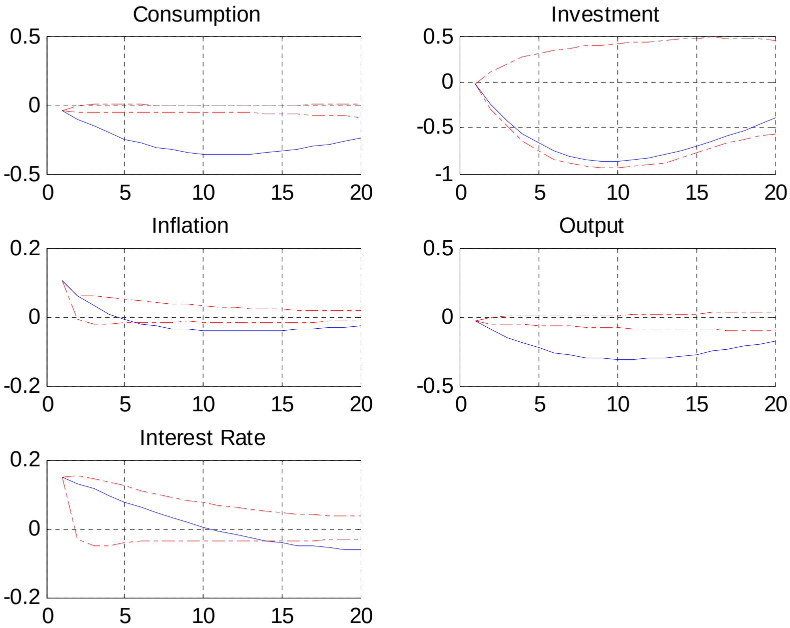

Figure 37: Wage Shock

E.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.91041	1.22728	FALSE	-2.15241
A_C^I	-0.09612	-2.57757	1.10832	TRUE	0.60488
A_C^π	0.01867	-0.24729	0.27012	TRUE	0.08997
A_C^Y	0.07935	-0.04299	0.29691	TRUE	-0.05363
A_C^R	-0.00824	-0.68692	0.71633	TRUE	-0.02851
A_I^C	-0.02461	0.00423	0.02888	FALSE	-6.63482
A_I^I	0.91856	0.72298	1.01137	TRUE	0.68703
A_I^π	-0.01074	-0.01640	0.02152	TRUE	-1.36353
A_I^Y	-0.01190	0.00013	0.02633	FALSE	-3.52462
A_I^R	-0.00504	-0.04887	0.05657	TRUE	-0.32041
A_π^C	-0.04105	-0.29748	0.68276	TRUE	-0.87091
A_π^I	-0.71538	-1.88821	6.56158	TRUE	-1.36168
A_π^π	0.68194	-1.42111	-0.02631	FALSE	3.97181
A_π^Y	-0.00692	-0.24770	0.75077	TRUE	-1.04893
A_π^R	-0.01605	-3.55009	0.30889	TRUE	1.59939
A_Y^C	0.21989	-0.28534	0.09633	FALSE	3.14871
A_Y^I	0.38855	-1.78860	2.38486	TRUE	0.09804
A_Y^π	0.05457	-0.29423	0.29445	TRUE	0.37461
A_Y^Y	0.93795	0.60214	1.00621	TRUE	0.84912
A_Y^R	0.06281	-0.79453	0.86200	TRUE	0.09647
A_R^C	-0.37666	-0.24619	0.15052	FALSE	-3.50362
A_R^I	-0.97612	-3.86893	-0.52126	TRUE	1.42940
A_R^π	-0.05704	0.38968	0.94054	FALSE	-5.18501
A_R^Y	-0.40669	-0.35330	0.04728	FALSE	-2.57877
A_R^R	0.89695	0.72418	2.32554	TRUE	-1.58522
	Wald Statistic	99.6			

*t-stat from bootstrap mean

Table 20: VAR Parameters & Model Bootstrap Bounds (Flexprice model with SW rhos and variances of innovations)

E.4 Results for SW's Model (ρs as set by SW, matching SW variances)

	Prod	Cons	Gov	Inv	Price	Int	Wage
ρ	0.828	0.886	0.956	0.917	0	0	0

Table 21: AR Coefficients and Variances of Shocks for SW's Model with SW rhos and variances of innovations

	Full varcovar	Just variances
VAR(1)	100	99.6

Table 22: Wald Statistics for Flexprice Model with SW rhos and variances of innovations

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	0.4520	65.1842	0.2169	0.3430	1.2866
Upper	6.5559	639.3290	0.9165	6.7867	5.3650
Mean	2.3150	255.9614	0.4616	2.1639	2.7127

Table 23: Variance of Data and Bootstraps for Flexprice Model with SW rhos and variances of innovations

	Prod	Cons	Gov	Inv	Price	Wage	TOTAL
C	3.317	91.432	0.845	4.401	0.001	0.004	100
I	0.361	95.649	0.021	3.969	0.000	0.000	100
K	0.292	95.032	0.033	4.643	0.000	0.000	100
L	5.504	86.602	3.838	4.046	0.003	0.008	100
π	2.175	97.125	0.040	0.158	0.245	0.257	100
Q	1.105	95.193	0.011	3.677	0.003	0.010	100
R	1.939	97.737	0.036	0.167	0.030	0.092	100
rk	0.334	94.903	0.139	4.624	0.000	0.000	100
W	4.152	91.267	0.134	4.447	0.000	0.000	100
Y	3.024	91.446	1.051	4.475	0.001	0.003	100

Table 24: Variance Decomposition for SW's Model with SW rhos and variances of innovations

E.5 Cross-Correlations for SW's Model (ρs as set by SW, matching SW variances)

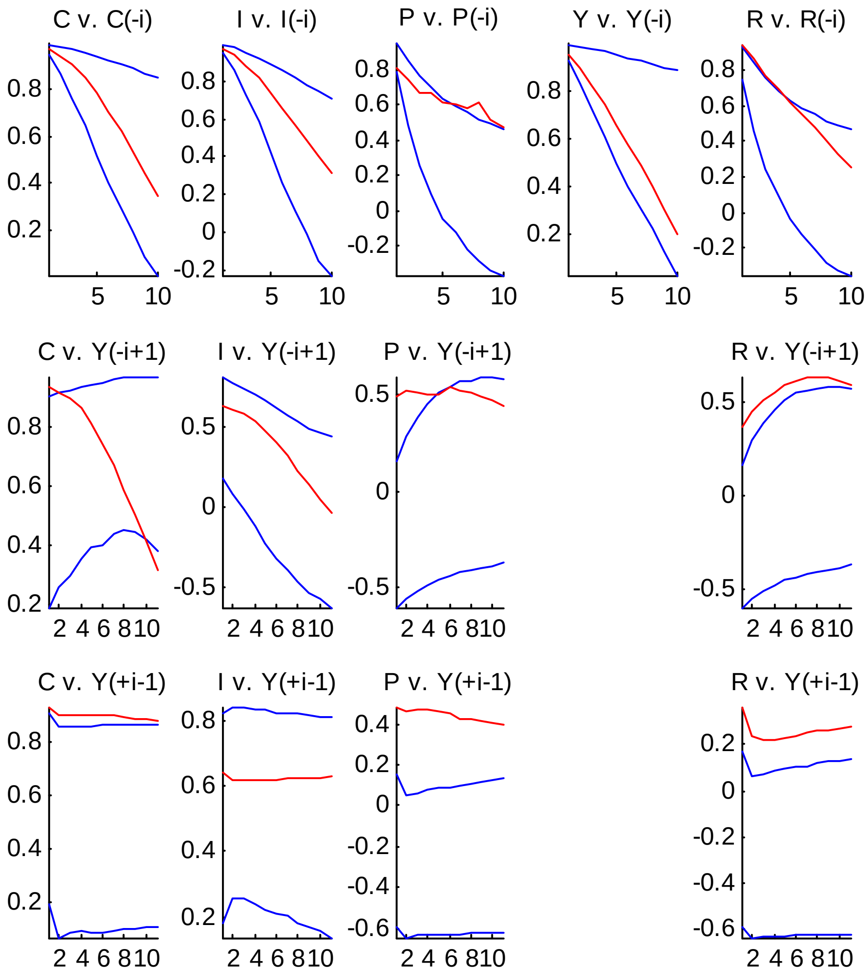

Figure 38: Cross-Correlations for SW's Model with SW rhos

Appendix F SW's Model (ρs as set by SW) — scaling 0.12 times all shocks

F.1 Randomly selected Bootstraps versus Actual Data

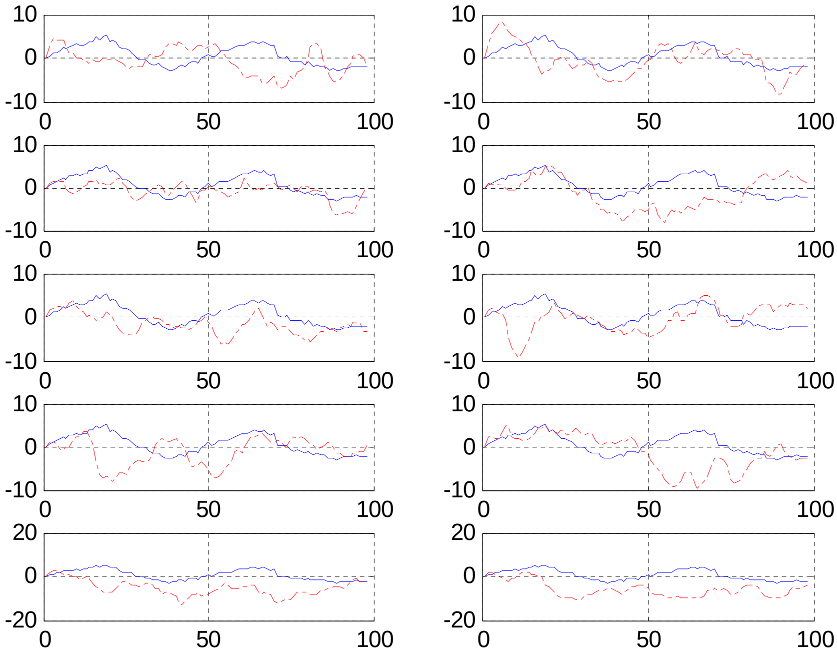

Figure 39: Consumption (Actual=blue, Simulated=red)

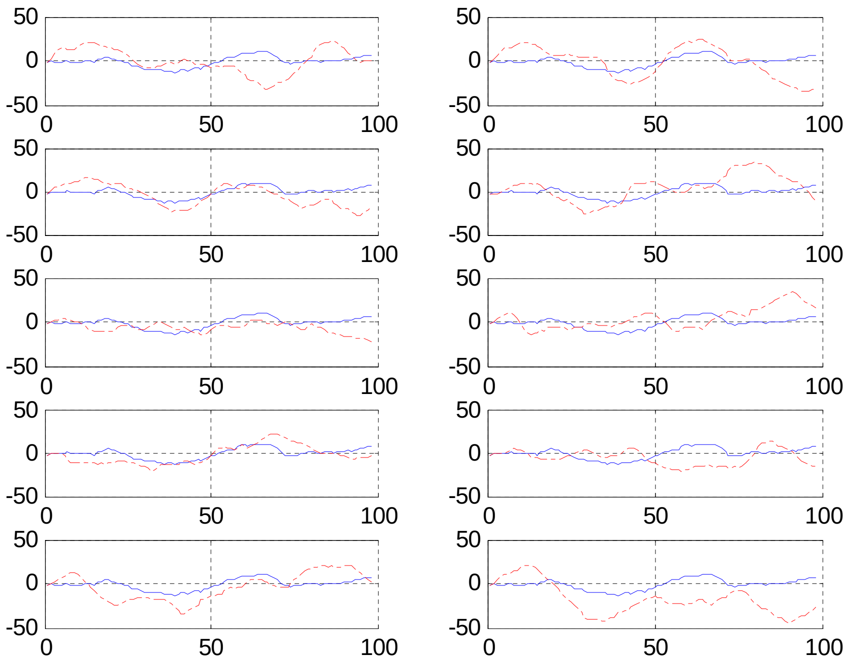

Figure 40: Investment (Actual=blue, Simulated=red)

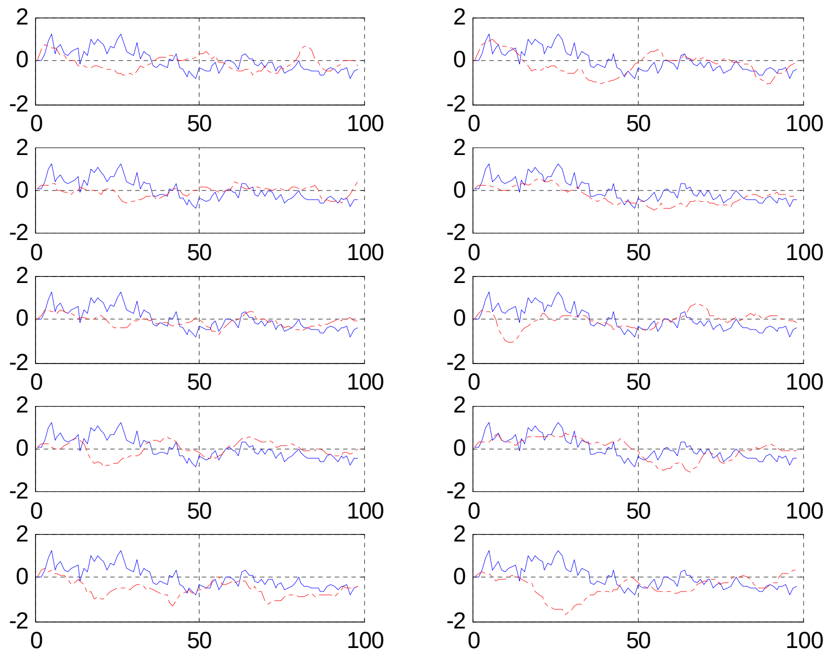

Figure 41: Inflation (Actual=blue, Simulated=red)

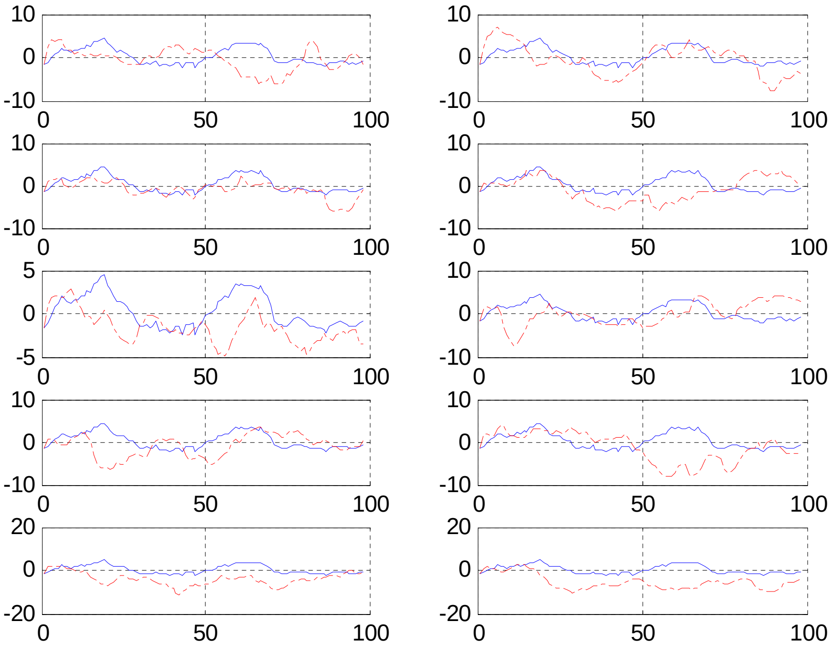

Figure 42: Output (Actual=blue, Simulated=red)

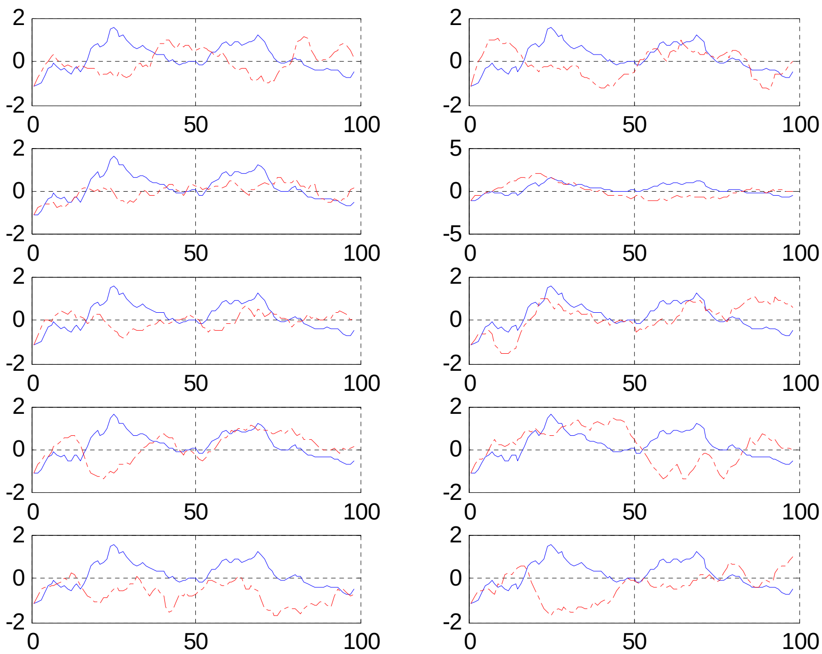

Figure 43: Interest Rate (Actual=blue, Simulated=red)

F.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

The red dotted lines denotes the upper and the lower bounds of the distribution of the IRF and the blue solid one is the IRF of the actual data.

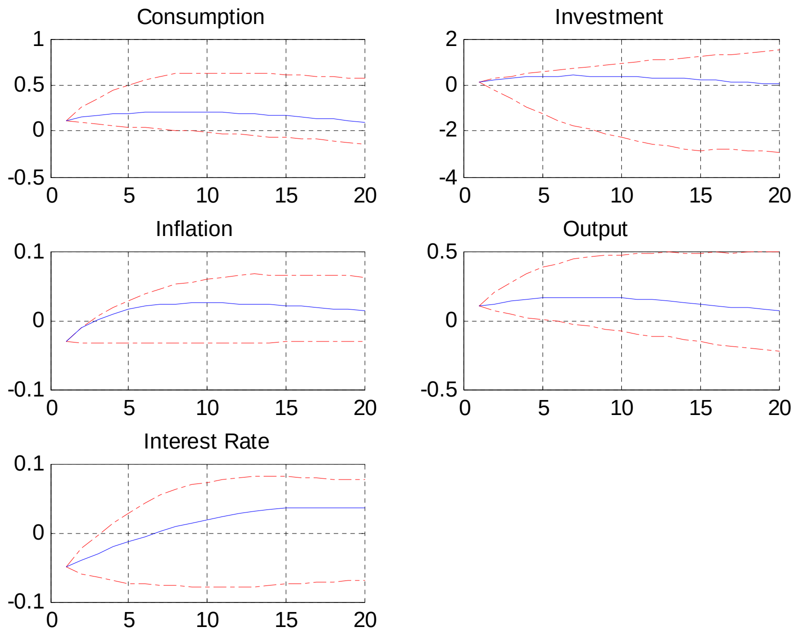

Figure 44: Productivity Shock

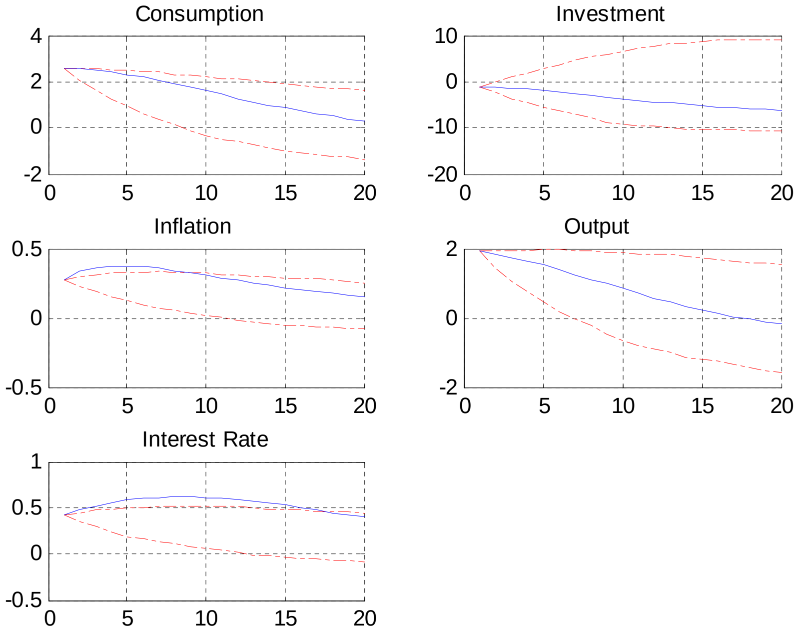

Figure 45: Consumer Preference Shock

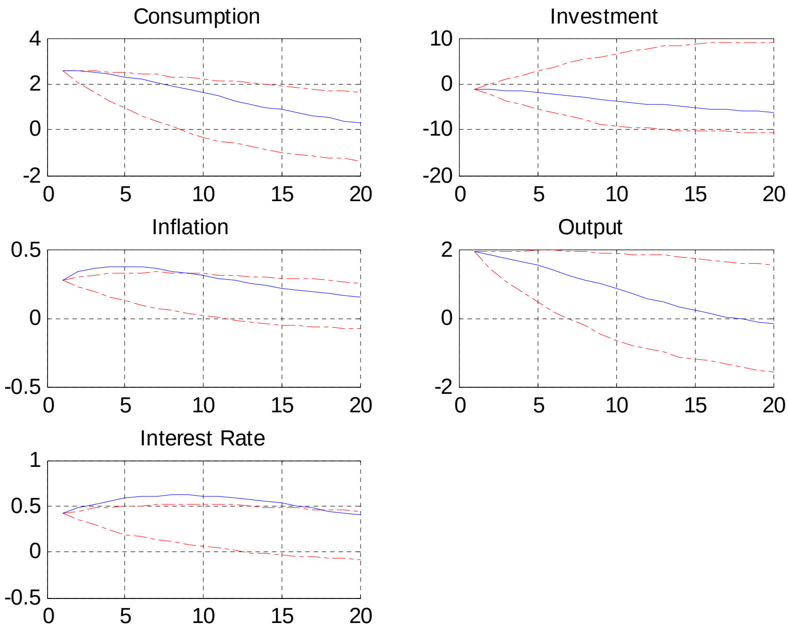

Figure 46: Government Spending Shock

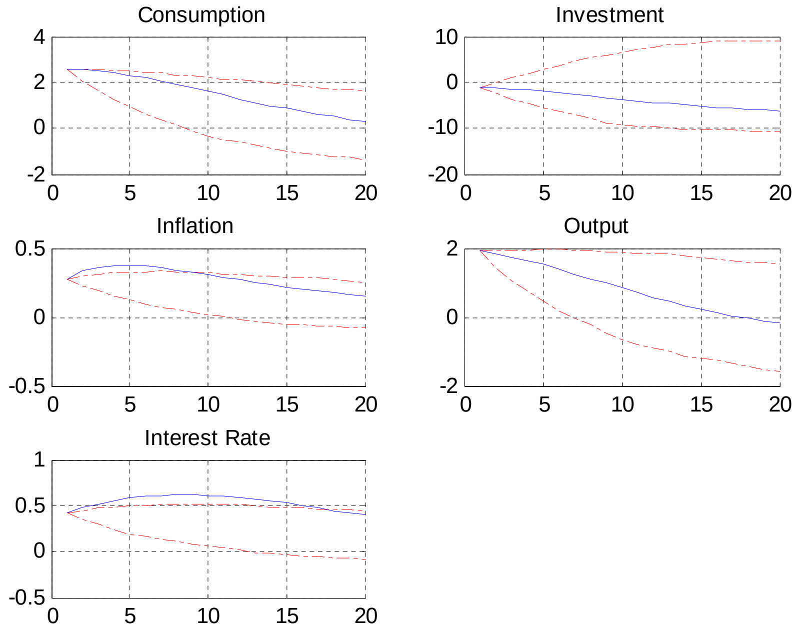

Figure 47: Investment Shock

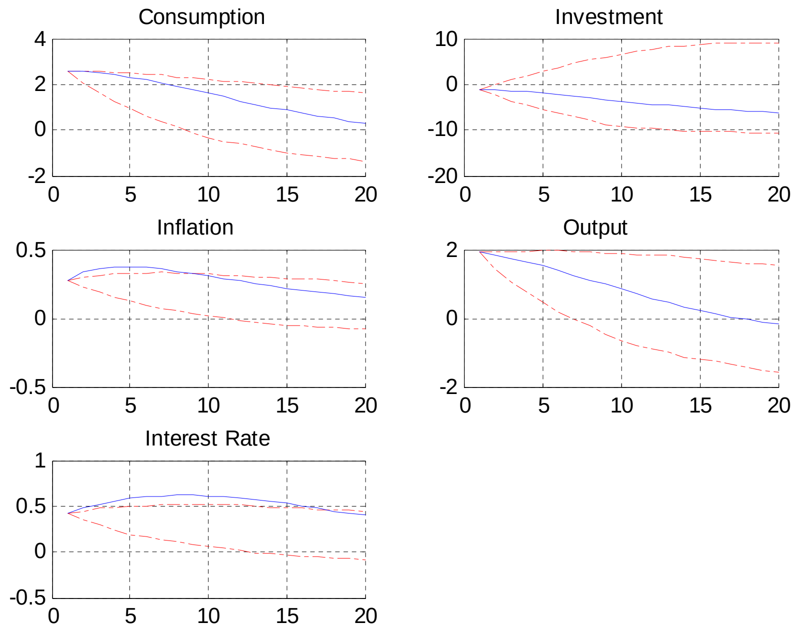

Figure 48: Price Shock

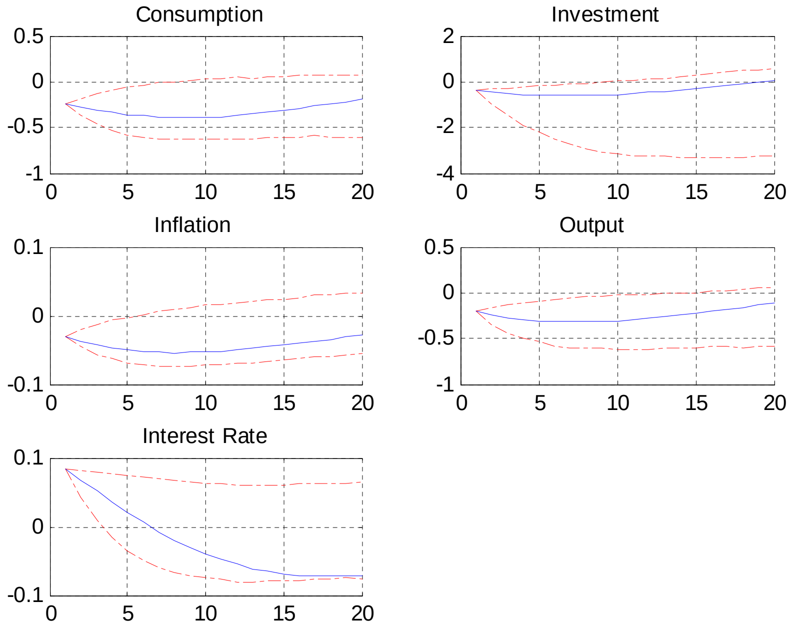

Figure 49: Monetary Shock

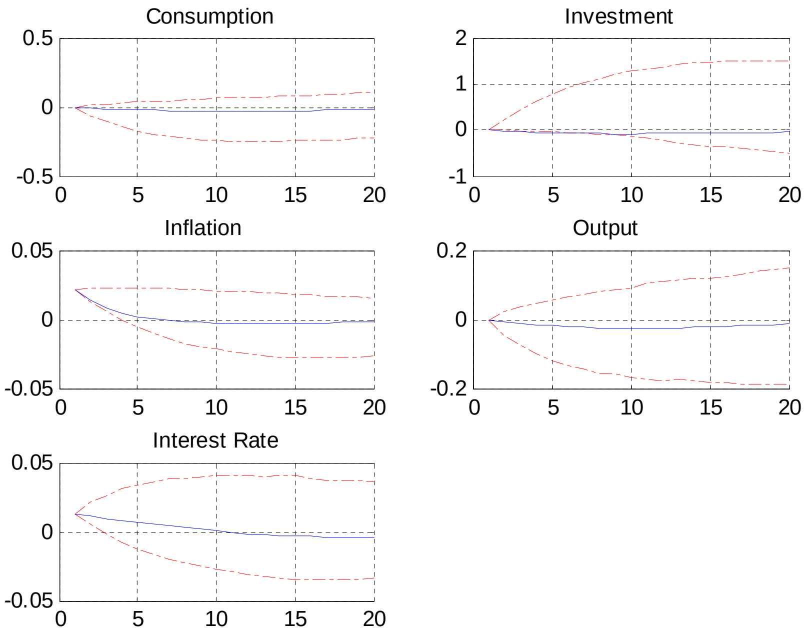

Figure 50: Wage Shock

F.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.67918	2.49208	TRUE	-1.52133
A_C^I	-0.09612	-3.31267	1.74690	TRUE	0.39735
A_C^π	0.01867	-0.01373	0.21096	TRUE	-1.33404
A_C^Y	0.07935	0.18841	1.72877	FALSE	-2.18954
A_C^R	-0.00824	-0.07416	0.25399	TRUE	-1.22432
A_I^C	-0.02461	-0.02682	0.11642	TRUE	-1.89608
A_I^I	0.91856	0.77144	1.16598	TRUE	-0.53039
A_I^π	-0.01074	-0.00346	0.01443	FALSE	-3.53605
A_I^Y	-0.01190	0.01440	0.13463	FALSE	-2.68931
A_I^R	-0.00504	-0.00586	0.02010	TRUE	-1.73155
A_π^C	-0.04105	-2.35017	1.30160	TRUE	0.27419
A_π^I	-0.71538	0.48847	12.25098	FALSE	-2.30655
A_π^π	0.68194	0.63691	1.10035	TRUE	-2.01048
A_π^Y	-0.00692	-1.71474	1.60154	TRUE	-0.19838
A_π^R	-0.01605	-0.26544	0.52533	TRUE	-0.80042
A_Y^C	0.21989	-1.91169	0.40898	TRUE	1.63957
A_Y^I	0.38855	-2.73577	3.64868	TRUE	0.04989
A_Y^π	0.05457	-0.26251	0.02661	FALSE	2.26469
A_Y^Y	0.93795	-1.23713	0.67523	FALSE	2.35942
A_Y^R	0.06281	-0.33688	0.10222	TRUE	1.64687
A_R^C	-0.37666	-1.36936	0.28395	TRUE	0.16286
A_R^I	-0.97612	-4.82771	0.42366	TRUE	0.75818
A_R^π	-0.05704	-0.15490	0.05127	TRUE	-0.29633
A_R^Y	-0.40669	-1.31530	0.17999	TRUE	0.26605
A_R^R	0.89695	0.63863	0.96598	TRUE	0.78643
	Wald Statistic	96.3			

*t-stat from bootstrap mean

Table 25: VAR Parameters & Model Bootstrap Bounds (SW model with SW rhos)

F.4 Results for SW's Model

	Prod	Cons	Gov	Inv	Price	Int	Wage
ρ	0.828	0.886	0.956	0.917	0	0	0
Var	0.784	0.259	0.324	1.557	0.061	1.094	0.270

Table 26: AR Coefficients and Variances of Shocks for SW's Model with SW rhos

	Full varcovar	Just variances
VAR(1)	100	96.3

Table 27: Wald Statistics for SW's Model with SW rhos

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	3.4200	64.5148	0.0519	2.5479	0.1318
Upper	21.8699	634.4155	0.2784	17.9432	0.6868
Mean	9.6729	253.8953	0.1320	7.8205	0.3109

Table 28: Variance of Data and Bootstraps for SW's Model with SW rhos

	Prod	Cons	Gov	Inv	Price	Int	Wage	TOTAL
C	0.196	46.626	0.146	40.137	0.036	12.845	0.015	100
I	0.063	11.286	0.005	83.234	0.018	5.388	0.005	100
K	0.053	12.110	0.008	84.169	0.012	3.644	0.005	100
L	1.283	47.488	0.758	33.509	0.043	16.888	0.030	100
π	0.164	74.453	0.026	7.739	2.032	15.426	0.160	100
Q	0.052	3.532	0.000	84.166	0.034	12.209	0.007	100
R	0.271	83.901	0.037	8.784	0.047	6.940	0.020	100
rk	0.109	25.387	0.063	69.313	0.032	5.029	0.067	100
W	0.119	22.654	0.017	62.138	0.144	14.310	0.617	100
Y	0.215	30.834	0.393	53.749	0.043	14.750	0.017	100

Table 29: Variance Decomposition for SW's Model with SW rhos

F.5 Cross-Correlations for SW's Model

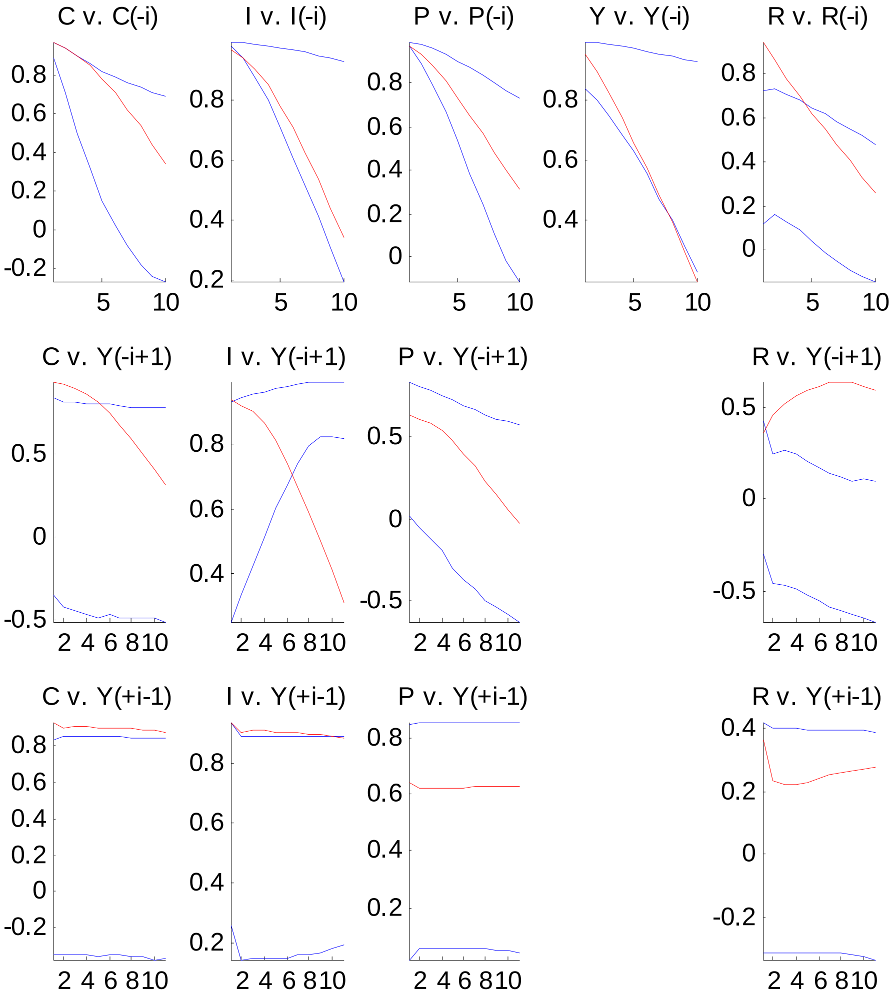

Figure 51: Cross-Correlations for SW's Model with SW rhos

Appendix G SW Model with re-estimated ρs — scaling 0.25 times all shocks

G.1 Randomly selected Bootstraps versus Actual Data (with estimated ρs)

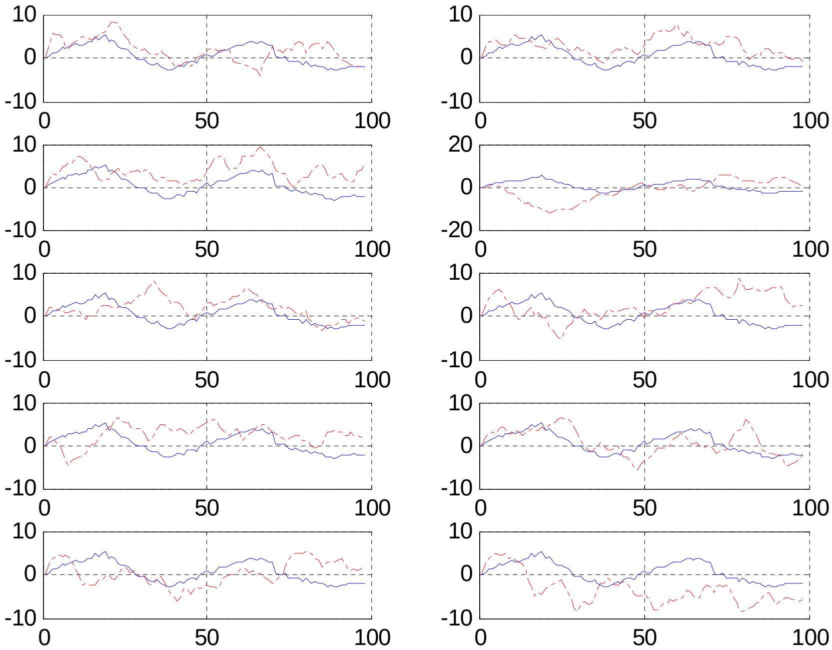

Figure 52: Consumption (Actual=blue, Simulated=red)

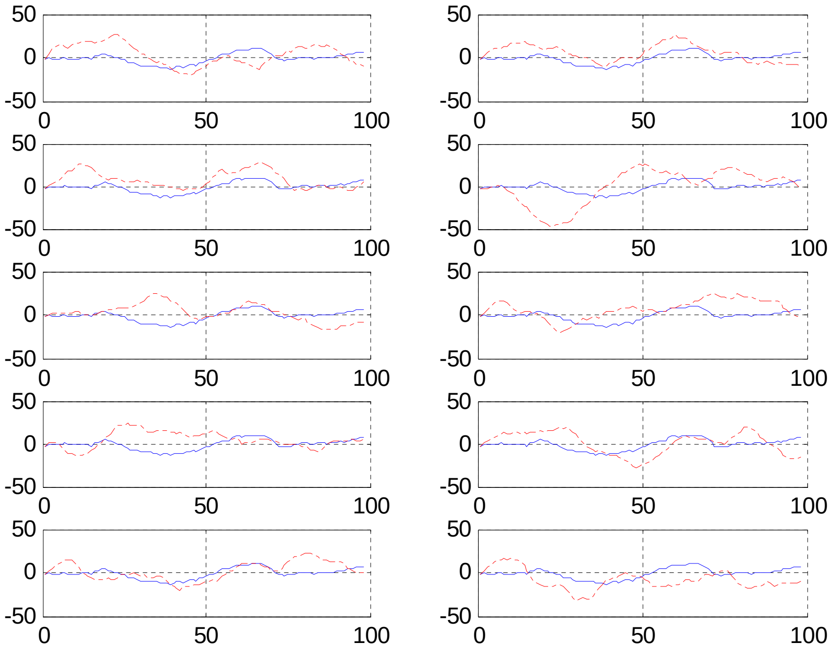

Figure 53: Investment (Actual=blue, Simulated=red)

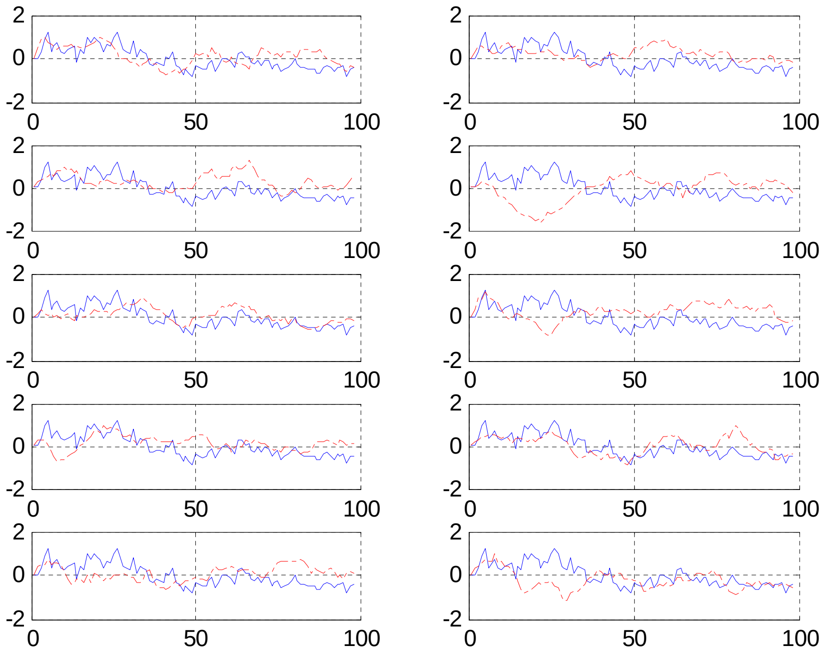

Figure 54: Inflation (Actual=blue, Simulated=red)

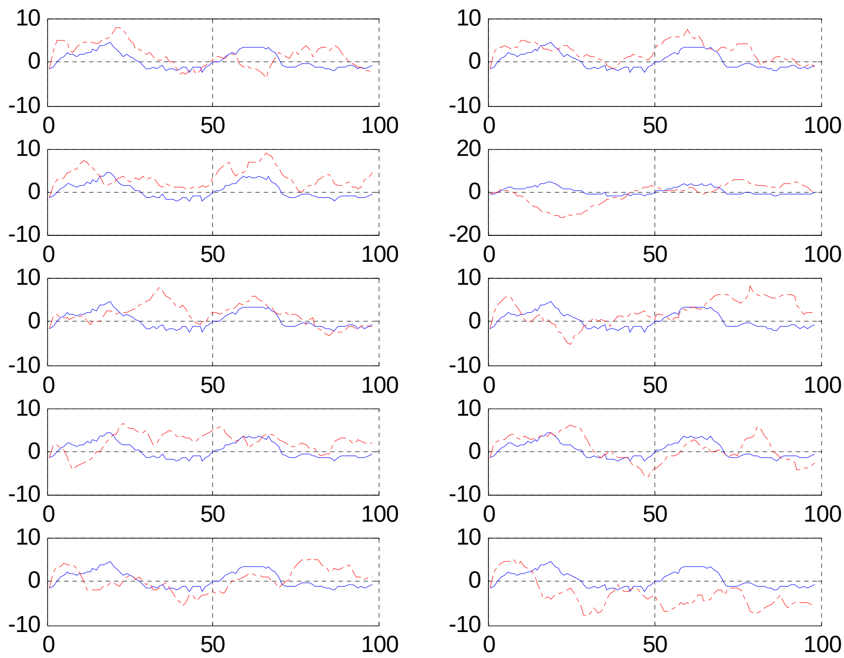

Figure 55: Output (Actual=blue, Simulated=red)

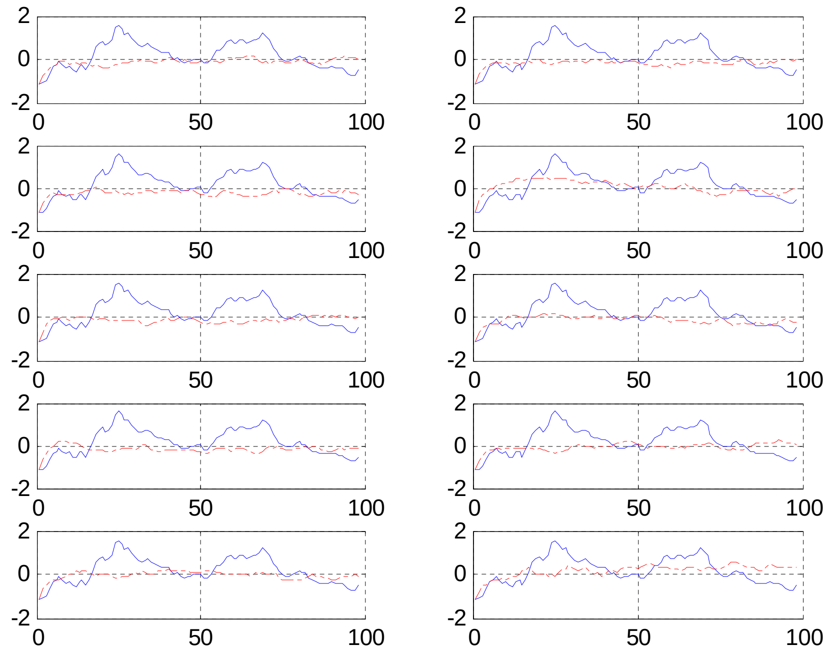

Figure 56: Interest Rate (Actual=blue, Simulated=red)

G.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model (with estimated shocks)

The red dotted lines denotes the upper and the lower bounds of the distribution of the IRF and the blue solid one is the IRF of the actual data.

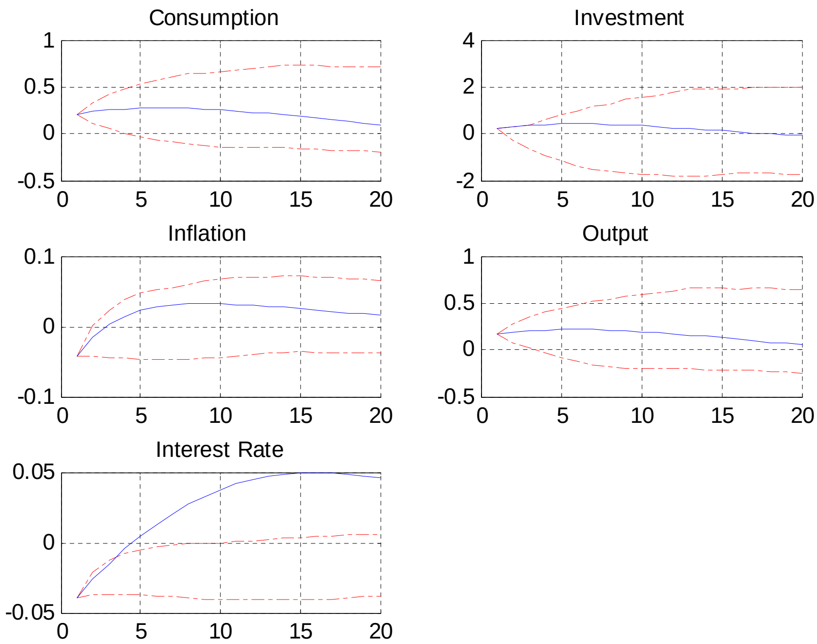

Figure 57: Productivity Shock

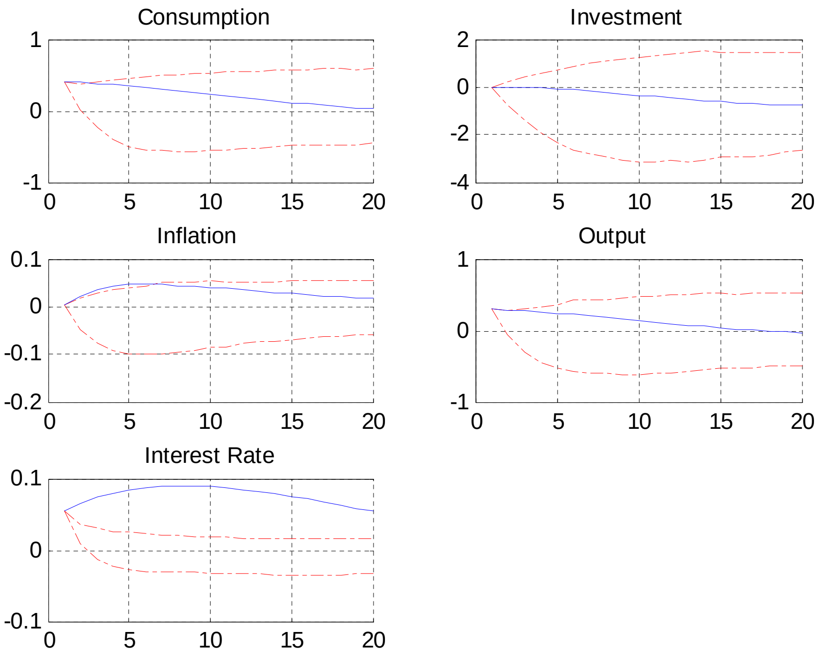

Figure 58: Preference Shock

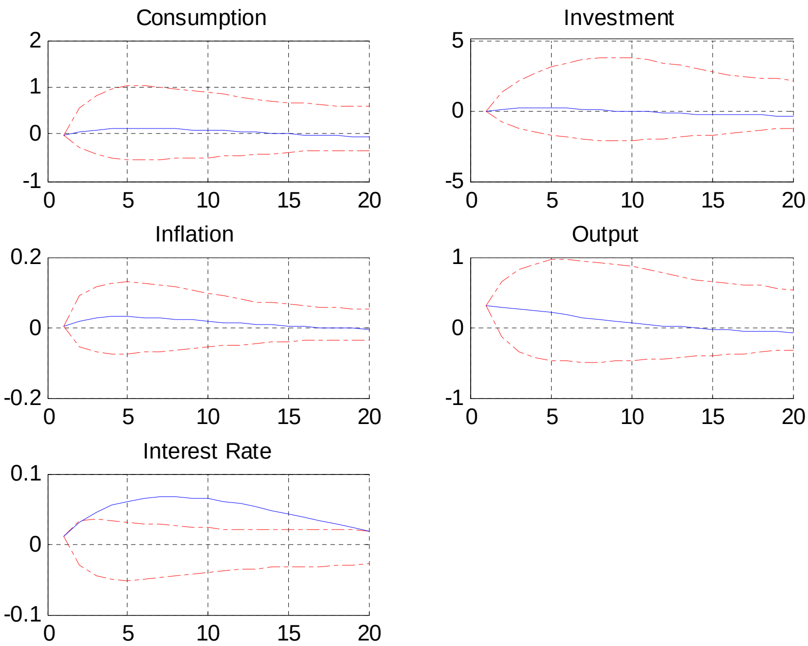

Figure 59: Government Spending Shock

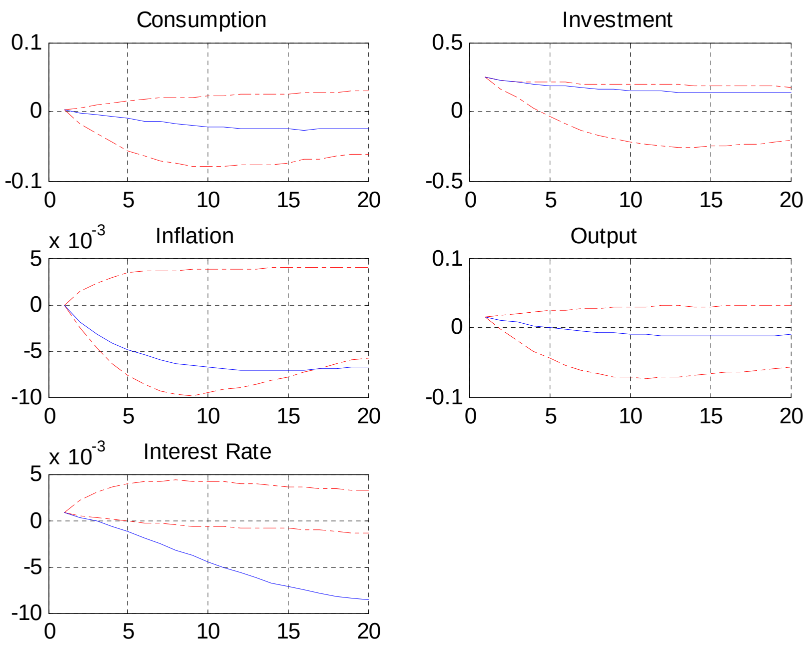

Figure 60: Investment Shock

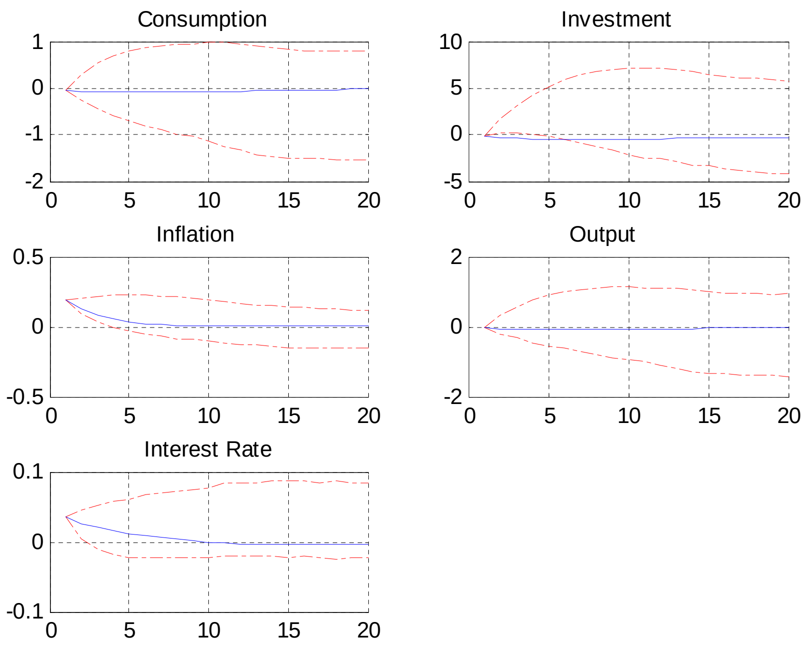

Figure 61: Price Shock

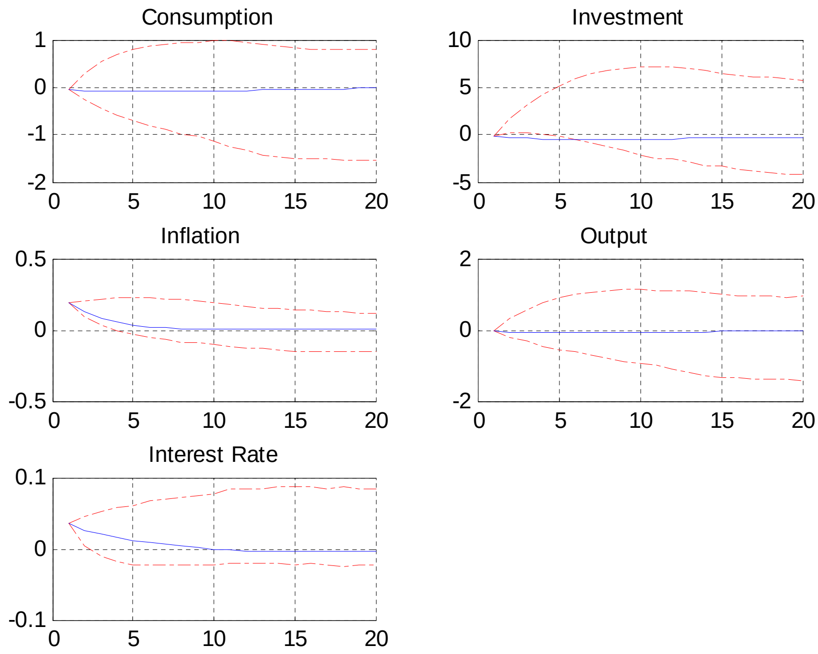

Figure 62: Monetary Shock

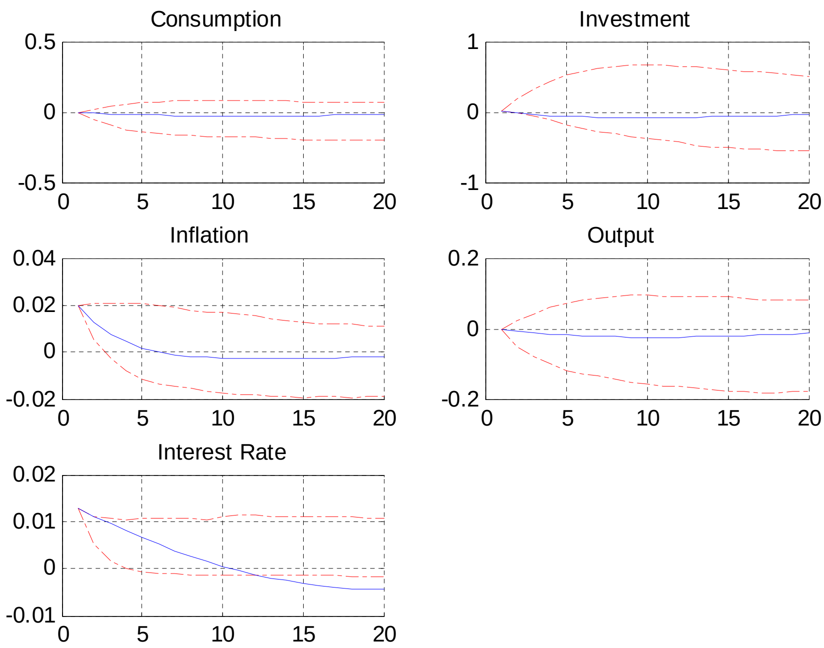

Figure 63: Wage Shock

G.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic (with estimated ρs)

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	-0.72761	1.56433	TRUE	0.726811
A_C^I	-0.09612	-3.67952	1.97243	TRUE	0.524598
A_C^π	0.01867	-0.25012	0.15093	TRUE	0.638875
A_C^Y	0.07935	-1.18984	0.97379	TRUE	0.329152
A_C^R	-0.00824	-0.10728	0.07514	TRUE	0.200019
A_I^C	-0.02461	-0.12365	0.02746	TRUE	0.496739
A_I^I	0.91856	0.59652	0.96120	TRUE	1.493974
A_I^π	-0.01074	-0.01690	0.00811	TRUE	-1.044040
A_I^Y	-0.01190	-0.08305	0.05315	TRUE	0.029549
A_I^R	-0.00504	-0.00099	0.00983	FALSE	-3.345770
A_π^C	-0.04105	-0.63612	2.05088	TRUE	-1.178840
A_π^I	-0.71538	1.97340	9.92243	FALSE	-3.585230
A_π^π	0.68194	0.54220	1.11755	TRUE	-1.412080
A_π^Y	-0.00692	-0.36242	2.13874	TRUE	-1.515170
A_π^R	-0.01605	-0.08937	0.11765	TRUE	-0.537700
A_Y^C	0.21989	-0.81029	1.85980	TRUE	-0.365960
A_Y^I	0.38855	-2.35381	4.09609	TRUE	-0.232430
A_Y^π	0.05457	-0.16908	0.27962	TRUE	0.038823
A_Y^Y	0.93795	-0.32156	2.14998	TRUE	0.094889
A_Y^R	0.06281	-0.11977	0.08366	TRUE	1.501961
A_R^C	-0.37666	-4.28405	-0.20281	TRUE	1.754145
A_R^I	-0.97612	-7.78487	1.53307	TRUE	0.896473
A_R^π	-0.05704	-0.65743	-0.00702	TRUE	1.625133
A_R^Y	-0.40669	-4.19901	-0.44180	FALSE	1.991061
A_R^R	0.89695	0.45640	0.75317	FALSE	3.782481
	Wald Statistic	93.6			

*t-stat from bootstrap mean

Table 30: VAR Parameters & Model Bootstrap Bounds (SW model with estimated rhos)

G.4 Results for SW's Model (with estimated shocks)

	Prod	Cons	Gov	Inv	Price	Int	Wage
ρ	0.940	-0.101	0.751	0.063	-0.154	0.565	-0.038
Var	0.784	0.259	0.324	1.557	0.061	1.094	0.270

Table 31: AR Coefficients and Variances of Shocks for SW's Model (with estimated rhos)

	Full varcovar	Just variances
VAR(1)	100	93.6

Table 32: Wald statistics for SW's Model (with estimated rhos)

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	3.5651	47.5781	0.0745	3.3518	0.0244
Upper	23.6006	409.0063	0.3819	22.1150	0.0808
Mean	10.2900	168.5409	0.1857	9.8493	0.0442

Table 33: Variance of Data and Bootstraps for SW's Model (with estimated rhos)

	Prod	Cons	Gov	Inv	Price	Int	Wage	TOTAL
C	2.875	0.163	0.007	0.056	0.033	96.845	0.021	100
I	1.361	0.000	0.003	0.586	0.037	97.995	0.017	100
K	2.521	0.000	0.004	0.376	0.034	97.044	0.021	100
L	2.612	0.161	0.296	0.063	0.031	96.806	0.032	100
π	0.651	0.002	0.003	0.010	1.739	97.426	0.168	100
Q	0.140	0.005	0.002	0.075	0.042	99.724	0.012	100
R	6.430	1.099	0.190	0.137	0.399	91.511	0.234	100
rk	1.333	0.047	0.077	0.255	0.074	97.977	0.236	100
W	2.515	0.003	0.002	0.060	0.114	96.580	0.727	100
Y	2.565	0.108	0.196	0.077	0.034	97.001	0.020	100

Table 34: Variance Decompositon for SW model with estimated rhos

G.5 Cross-Correlations for SW's Model (with estimated ρs)

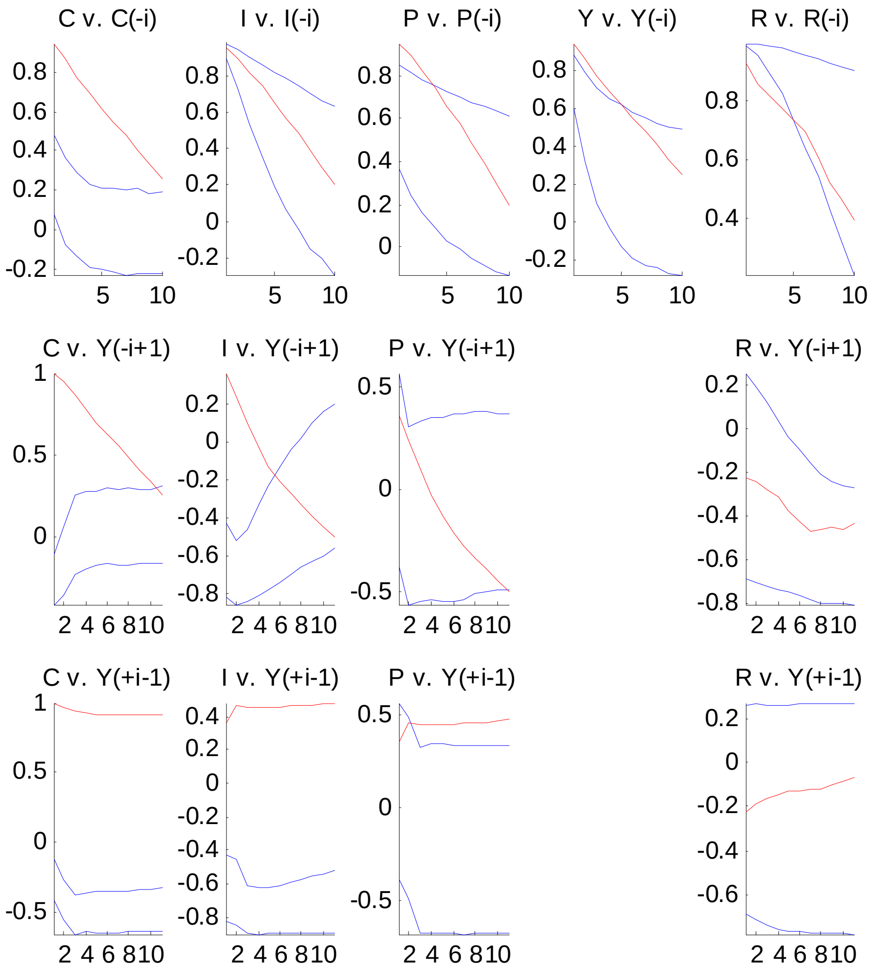

Figure 64: Cross-Correlations for SW's Model (with estimated rhos)

G.6 Deterministic Shock IRFs

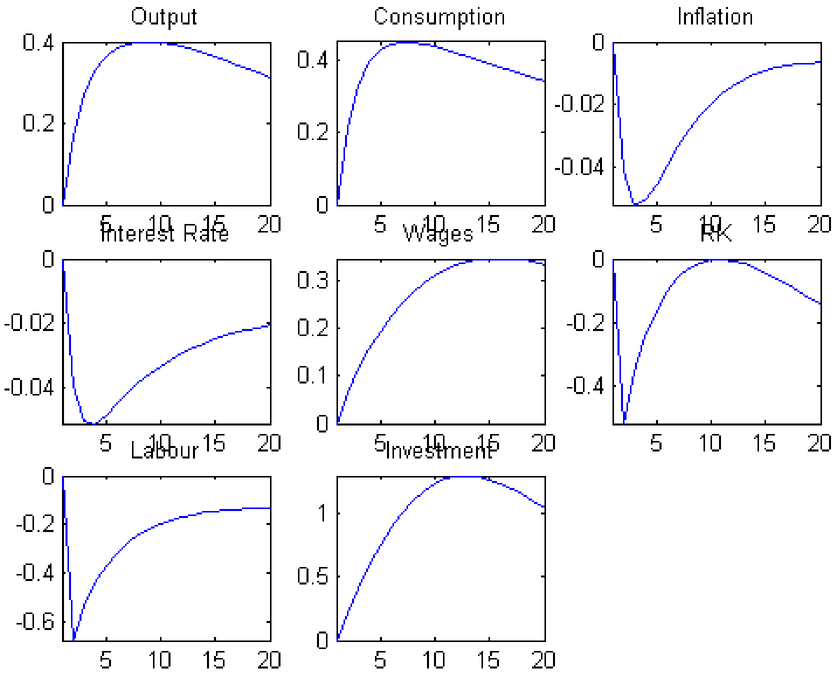

Figure 65: Productivity Shock

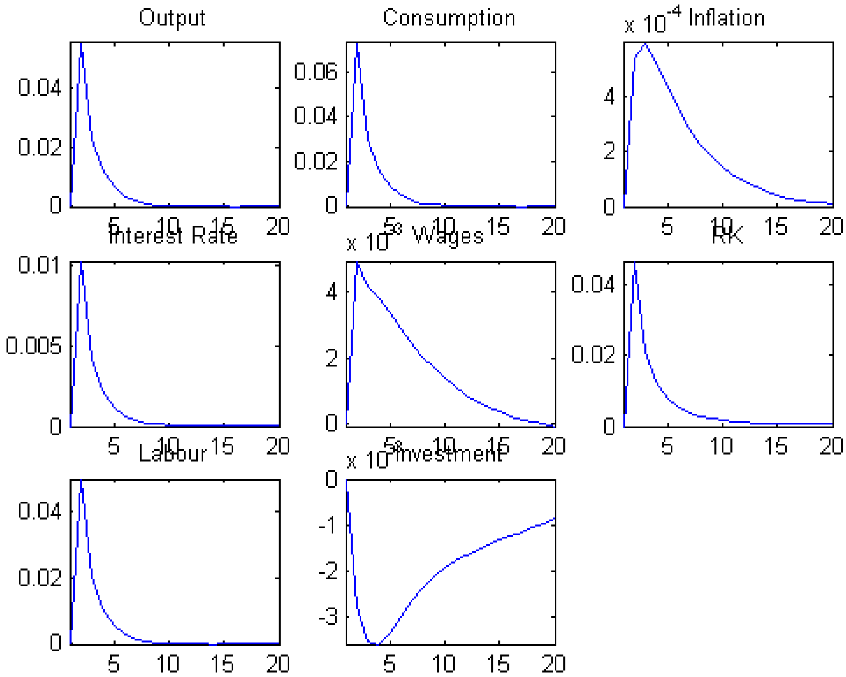

Figure 66: Preference Shock

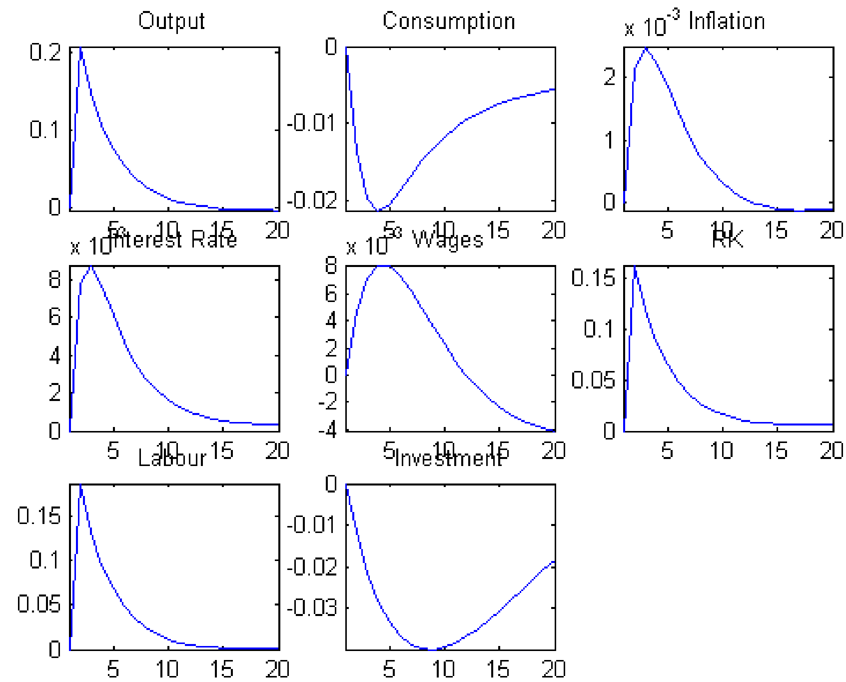

Figure 67: Governmend Spending Shock

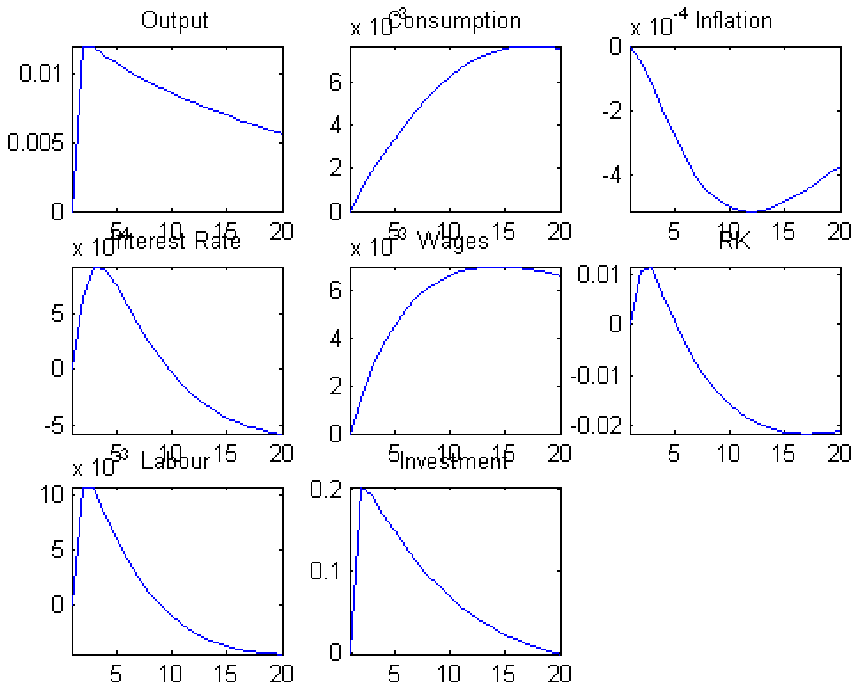

Figure 68: Investment Shock

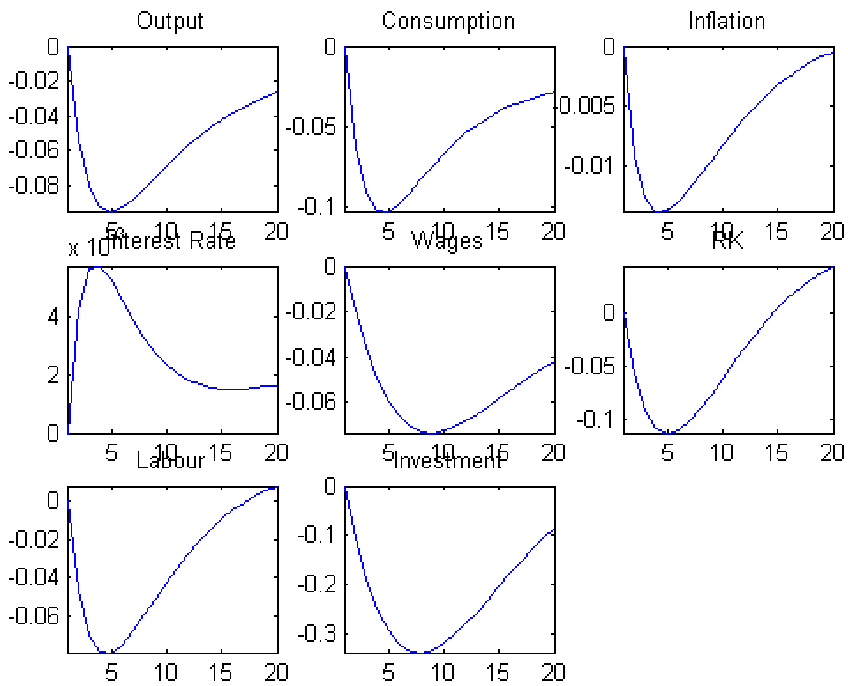

Figure 69: Monetary Shock

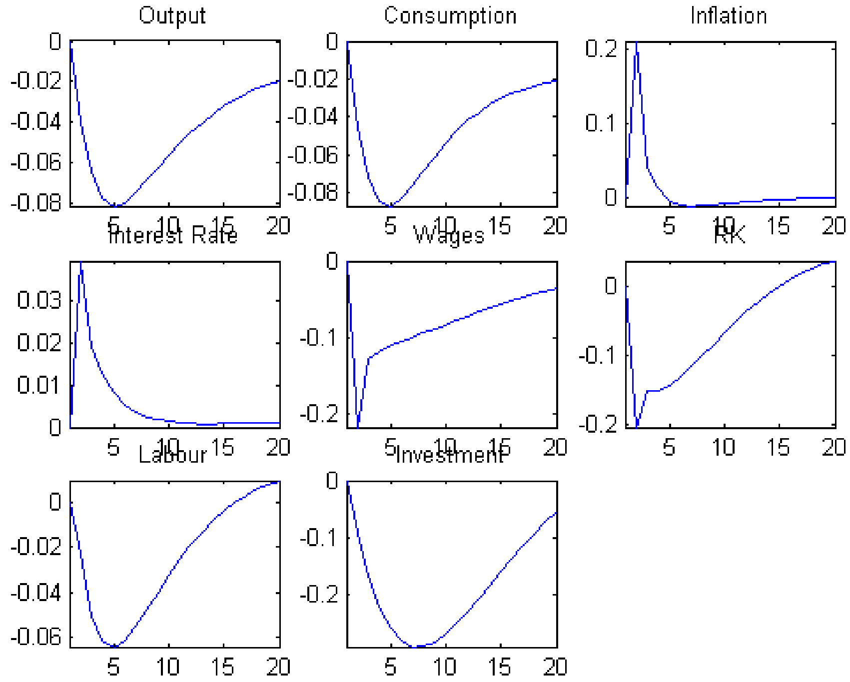

Figure 70: Price Shock

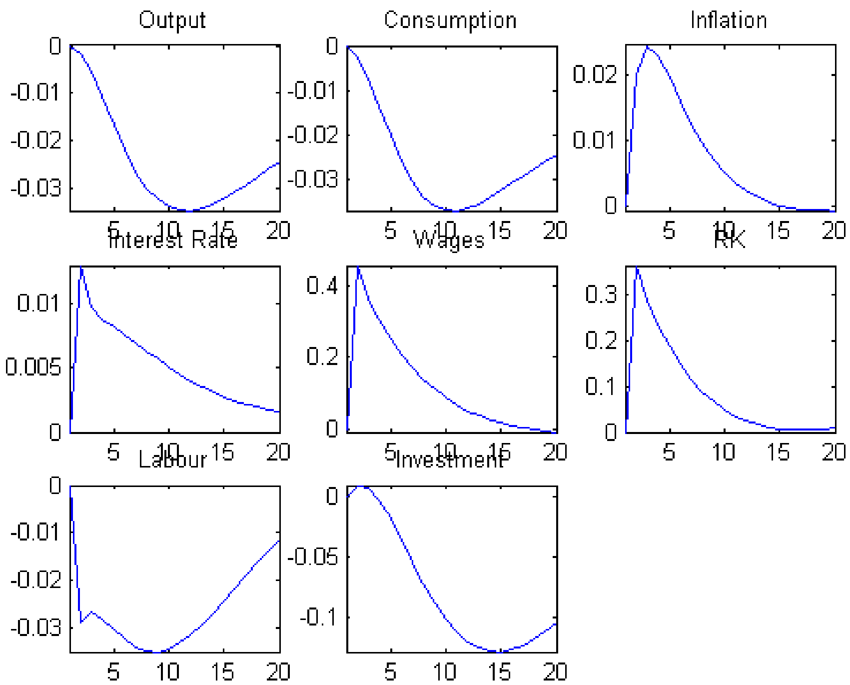

Figure 71: Wage Shock

Appendix H Flexprice (New Classical) Version of SW Model — scaling 0.67 times all shocks

H.1 Randomly selected Bootstraps versus Actual Data

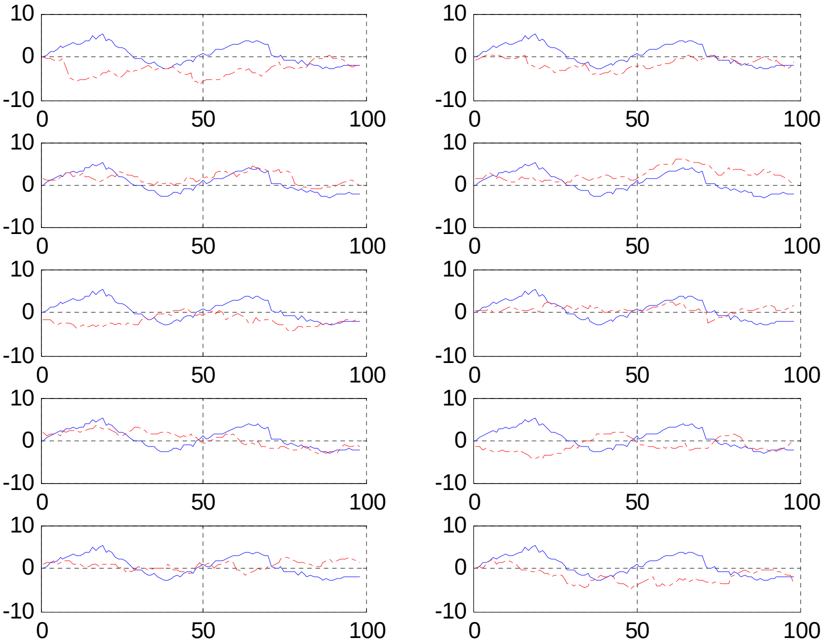

Figure 72: Consumption (Actual=blue, Simulated=red)

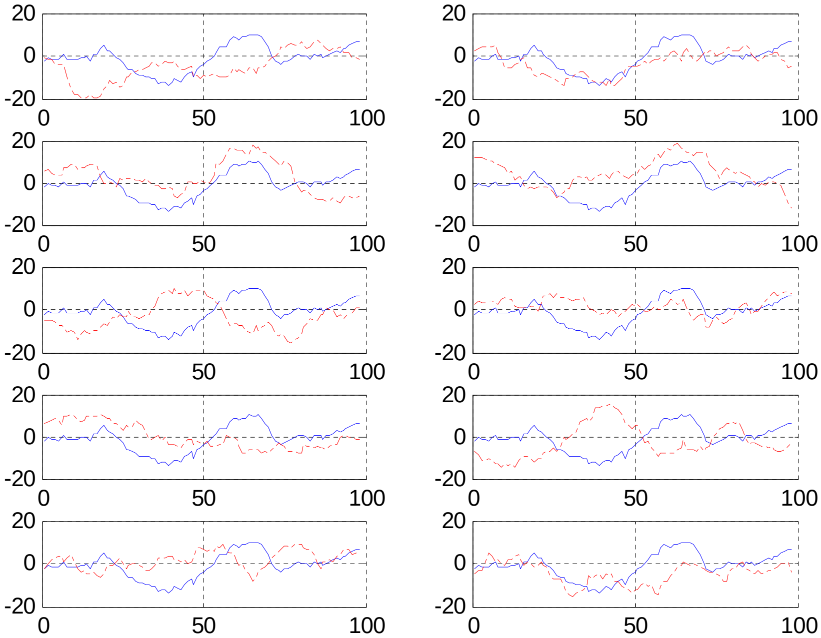

Figure 73: Investment (Actual=blue, Simulated=red)

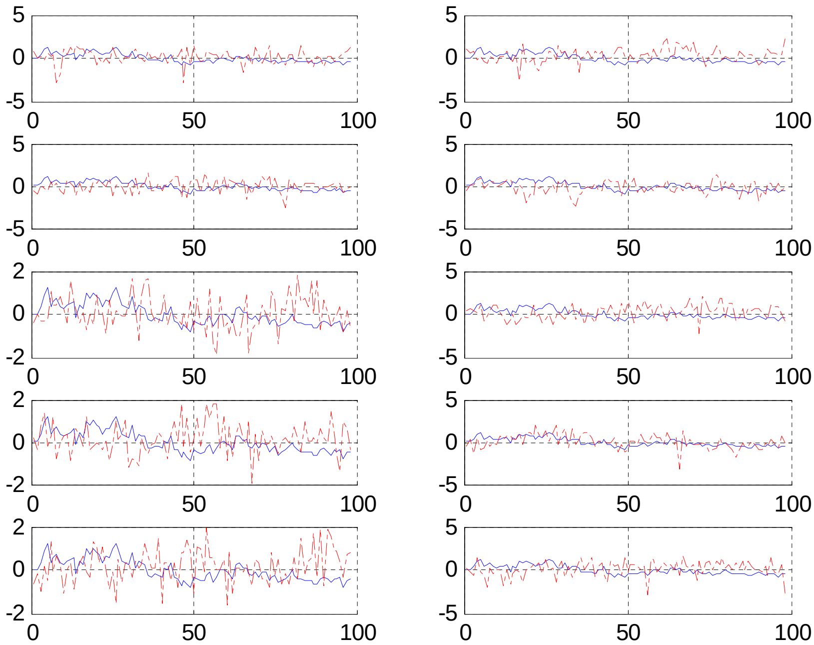

Figure 74: Inflation (Actual=blue, Simulated=red)

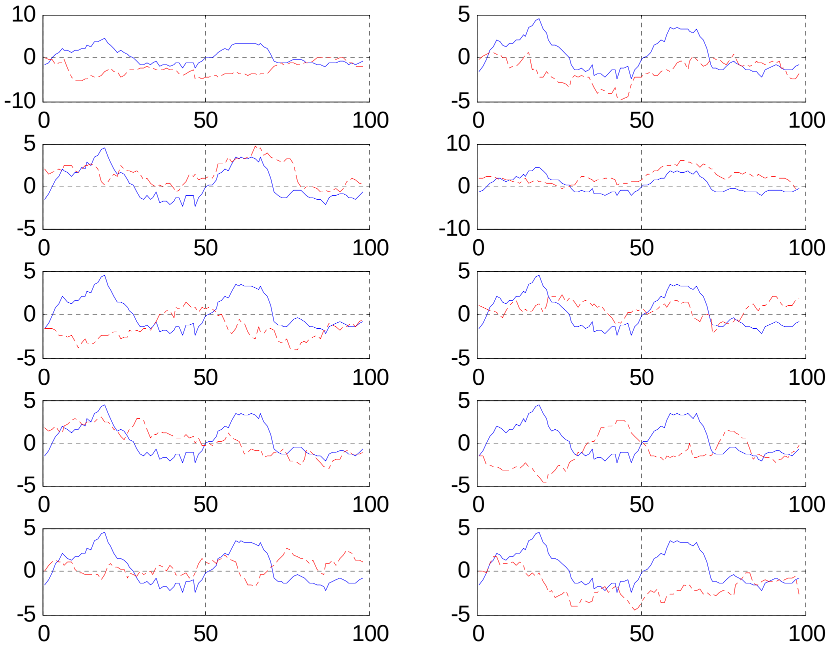

Figure 75: Output (Actual=blue, Simulated=red)

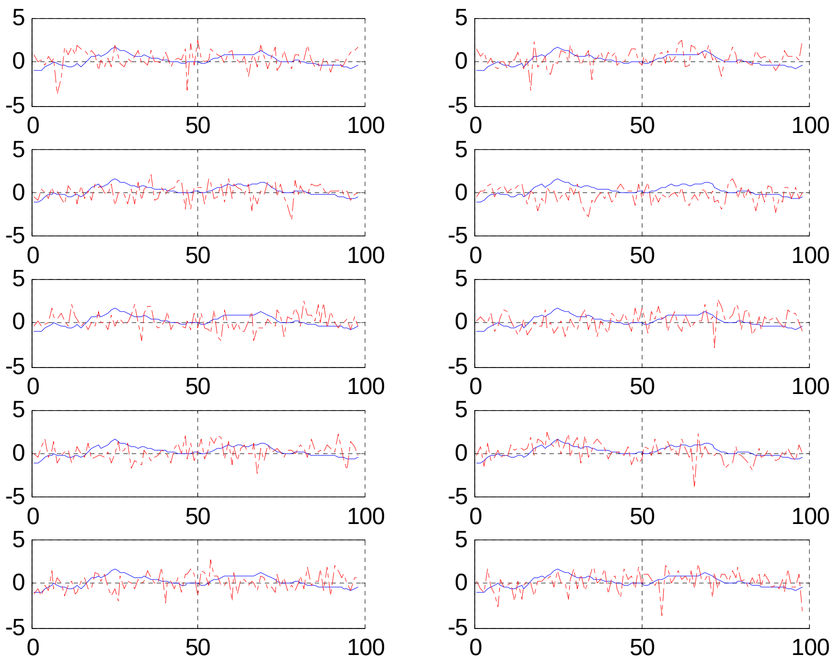

Figure 76: Interest Rate (Actual=blue, Simulated=red)

H.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

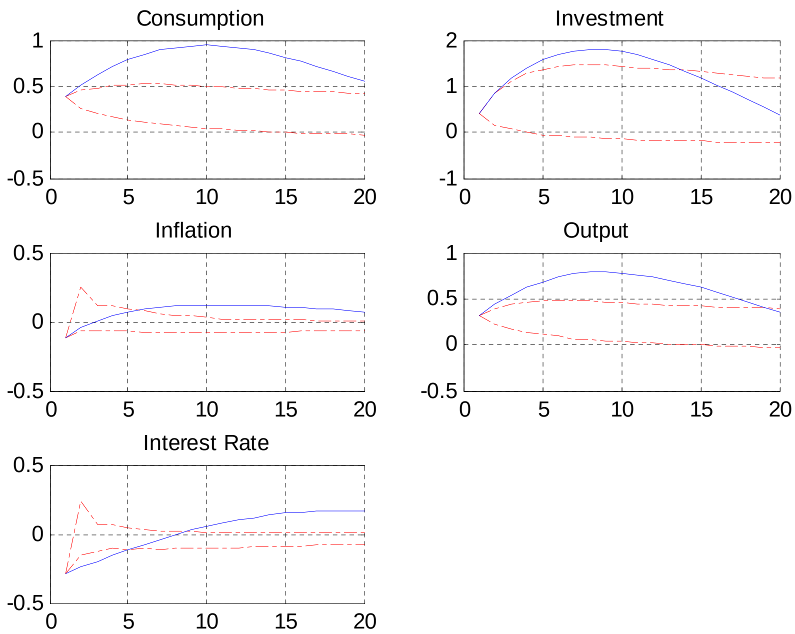

Figure 77: Productivity Shock

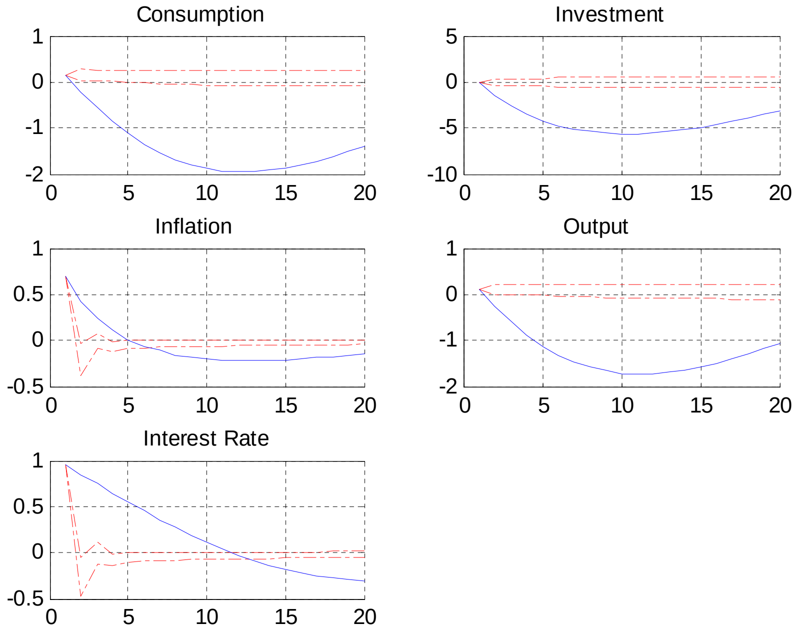

Figure 78: Consumer Preference Shock

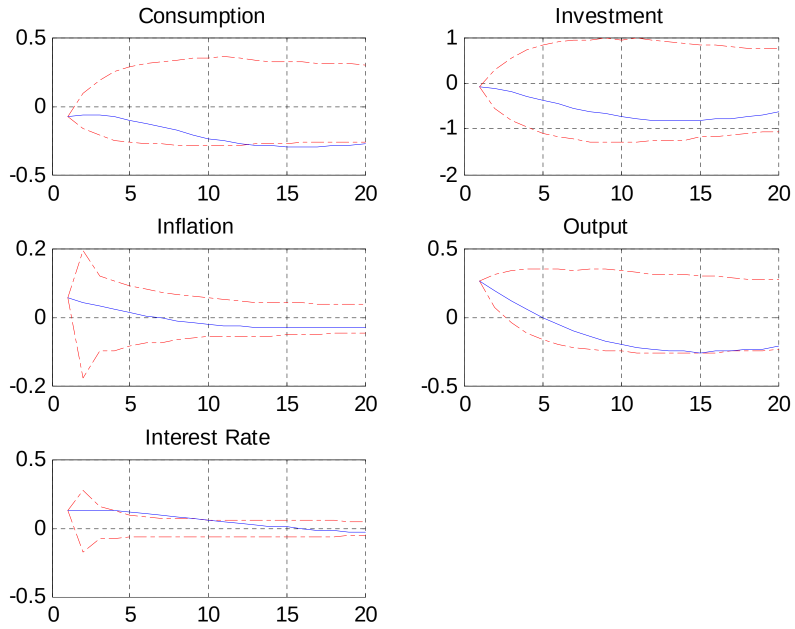

Figure 79: Government Spending Shock

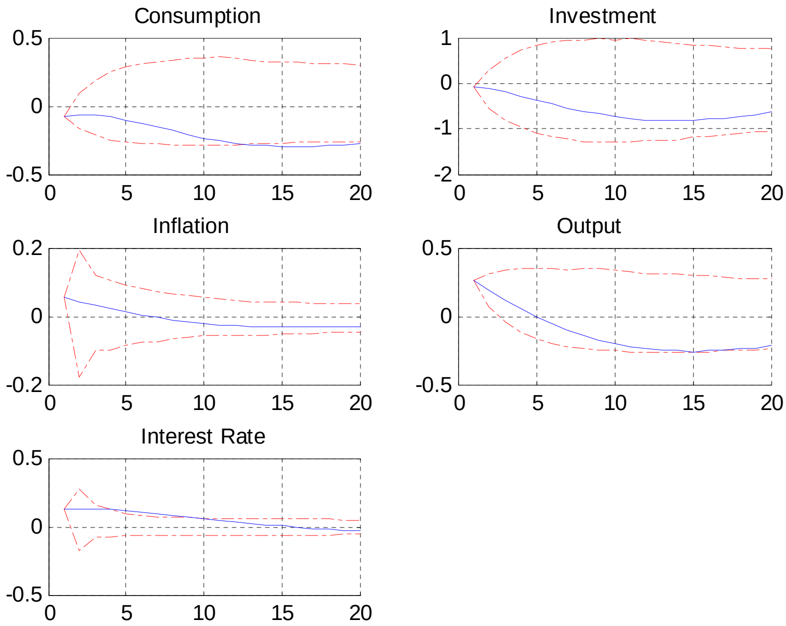

Figure 80: Investment Shock

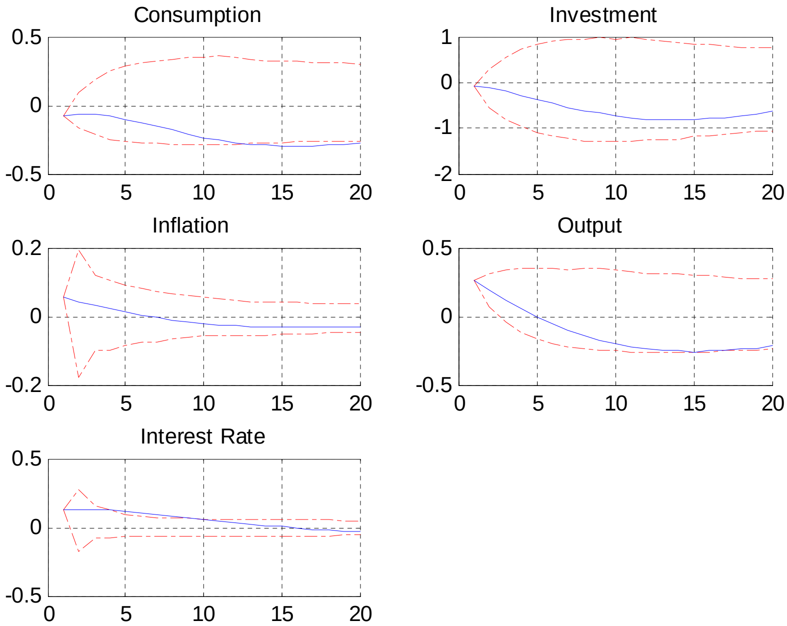

Figure 81: Price Shock

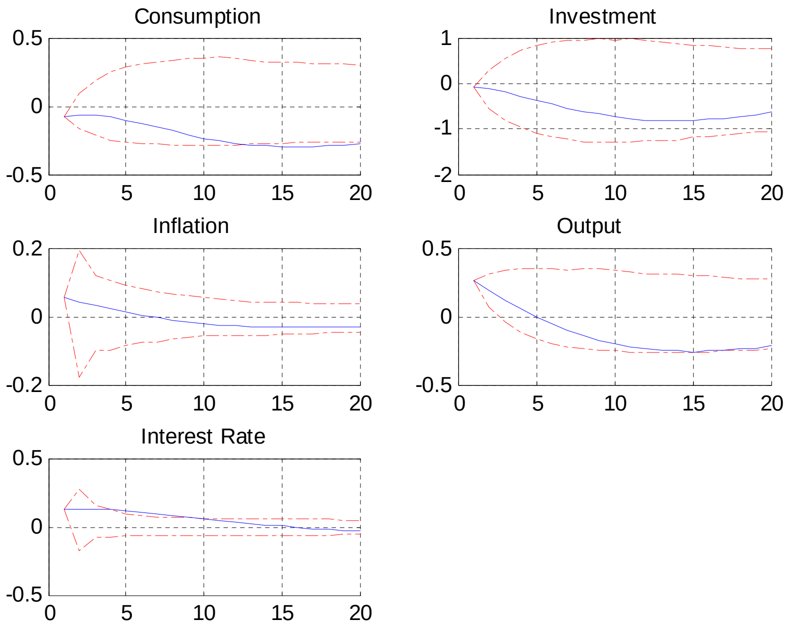

Figure 82: Wage Shock

H.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.52259	1.18525	TRUE	0.122919
A_C^I	-0.09612	-0.96369	1.27543	TRUE	-0.428420
A_C^π	0.01867	-0.97493	-0.01531	FALSE	1.965241
A_C^Y	0.07935	-0.17288	0.45474	TRUE	-0.360650
A_C^R	-0.00824	-1.23870	-0.03653	FALSE	1.970249
A_I^C	-0.02461	-0.06602	0.04563	TRUE	-0.694500
A_I^I	0.91856	0.68911	1.07953	TRUE	0.191476
A_I^π	-0.01074	-0.07240	0.09956	TRUE	-0.492110
A_I^Y	-0.01190	-0.04235	0.05387	TRUE	-0.766020
A_I^R	-0.00504	-0.08904	0.12880	TRUE	-0.371980
A_π^C	-0.04105	-0.94409	1.02284	TRUE	-0.295360
A_π^I	-0.71538	-2.79046	4.28830	TRUE	-0.926320
A_π^π	0.68194	0.16140	3.20631	TRUE	-1.457580
A_π^Y	-0.00692	-0.84830	1.03652	TRUE	-0.303820
A_π^R	-0.01605	-0.60757	3.17618	TRUE	-1.521040
A_Y^C	0.21989	-0.31978	0.50850	TRUE	0.562984
A_Y^I	0.38855	-1.38295	1.34478	TRUE	0.532472
A_Y^π	0.05457	-0.35789	0.84976	TRUE	-0.601120
A_Y^Y	0.93795	0.38835	1.13783	TRUE	0.855872
A_Y^R	0.06281	-0.39085	1.05363	TRUE	-0.645250
A_R^C	-0.37666	-0.81912	0.73652	TRUE	-0.804630
A_R^I	-0.97612	-3.31798	2.22810	TRUE	-0.186950
A_R^π	-0.05704	-2.57757	-0.25199	FALSE	2.374330
A_R^Y	-0.40669	-0.78257	0.66123	TRUE	-0.816010
A_R^R	0.89695	-2.64767	0.23123	FALSE	2.913874
	Wald Statistic	76.8			

*t-stat from bootstrap mean

Table 35: VAR Parameters & Model Bootstrap Bounds for Flex-price Model)

H.4 Results for Flex-Price Model

	Prod	Cons	Gov	Inv	Price	Int	Wage
ρ	0.940	-0.101	0.751	0.063	0.909	0.565	0.905
Var	0.784	0.259	0.324	1.557	0.510	0.900	25.021

Table 36: AR Coefficients and Variances of Shocks for Flex-Price Model

	Full varcovar	Just variances
VAR(1)	100	76.8

Table 37: Wald statistics for Flex-Price Model

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	0.7330	9.8999	0.4497	0.6434	0.6906
Upper	6.8787	84.0695	0.9583	5.6327	1.4368
Mean	2.4783	34.5926	0.6678	2.2226	1.0270

Table 38: Variance of Data and Bootstraps for Flex-Price Model

	Prod	Cons	Gov	Inv	Price	Wage	TOTAL
c	35.360	0.237	0.385	0.495	0.032	63.491	100
I	27.903	0.060	0.219	8.488	0.001	63.329	100
K	34.697	0.027	0.135	3.689	0.000	61.451	100
L	25.517	0.278	2.209	0.442	0.046	71.508	100
π	1.739	31.512	0.440	0.083	57.973	8.252	100
Q	15.320	13.421	1.516	2.547	0.638	66.558	100
R	5.607	36.900	1.372	0.301	28.975	26.846	100
rk	31.196	0.090	0.656	4.285	0.010	63.763	100
w	83.085	0.022	0.161	1.053	0.002	15.675	100
$E_{t-1}\pi_t$	1.773	0.858	0.408	0.133	88.228	8.599	100
Y	34.437	0.152	1.182	0.531	0.025	63.673	100

Table 39: Variance Decompositon for Flex-Price Model

H.5 Cross-Correlations for Flex-Price Model

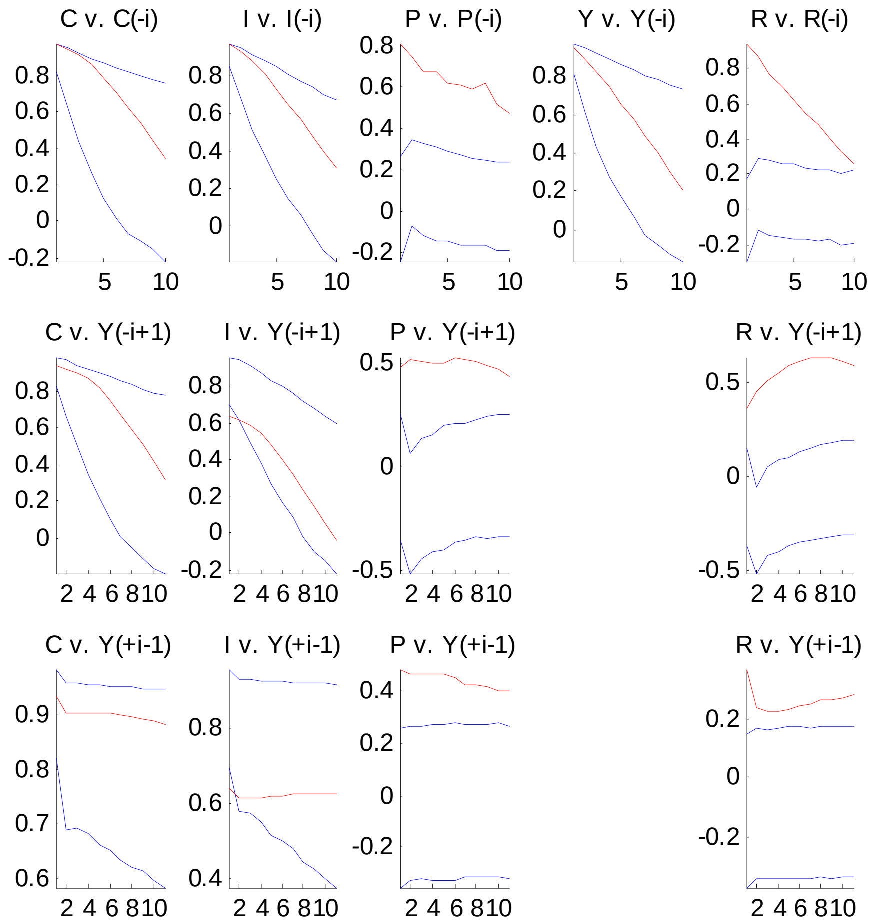

Figure 83: Cross-Correlations for Flex-Price Model

H.6 Deterministic Shock IRFs

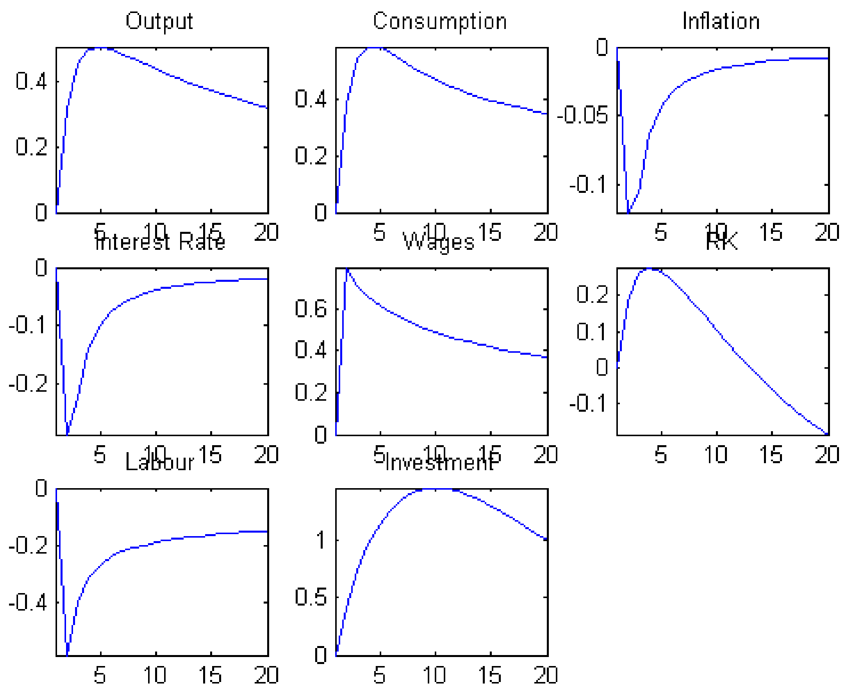

Figure 84: Productivity Shock

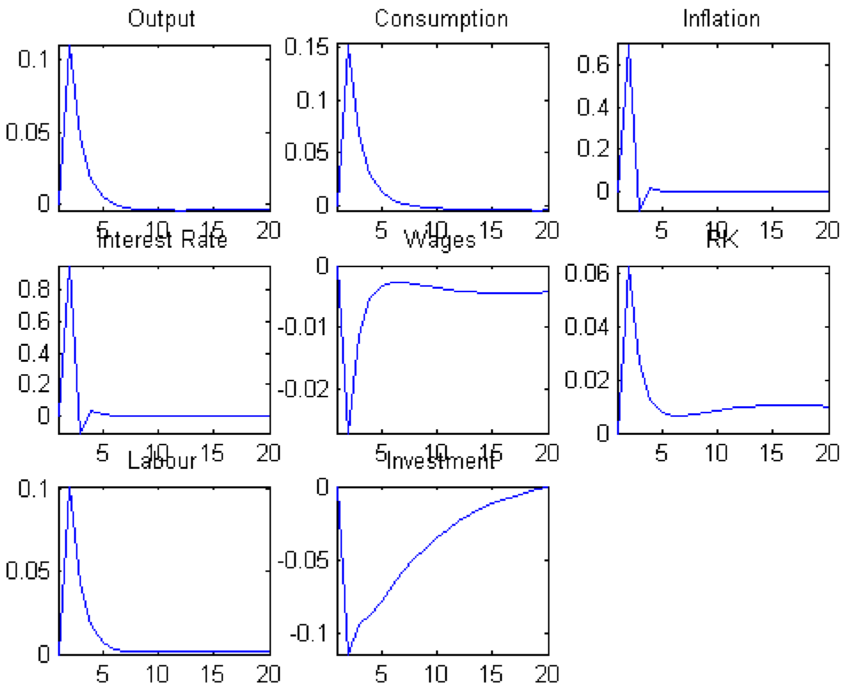

Figure 85: Preference Shock

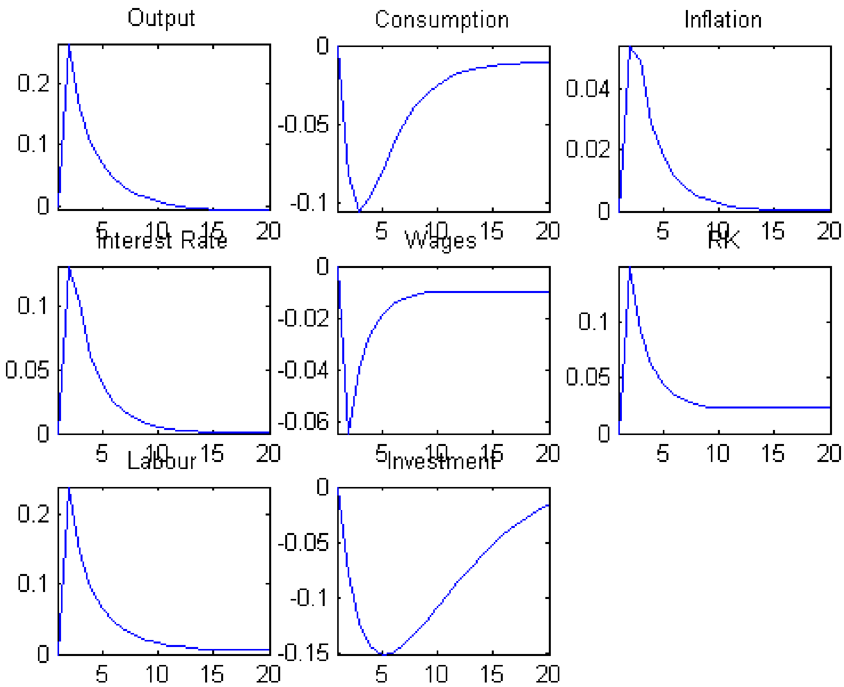

Figure 86: Government Spending Shock

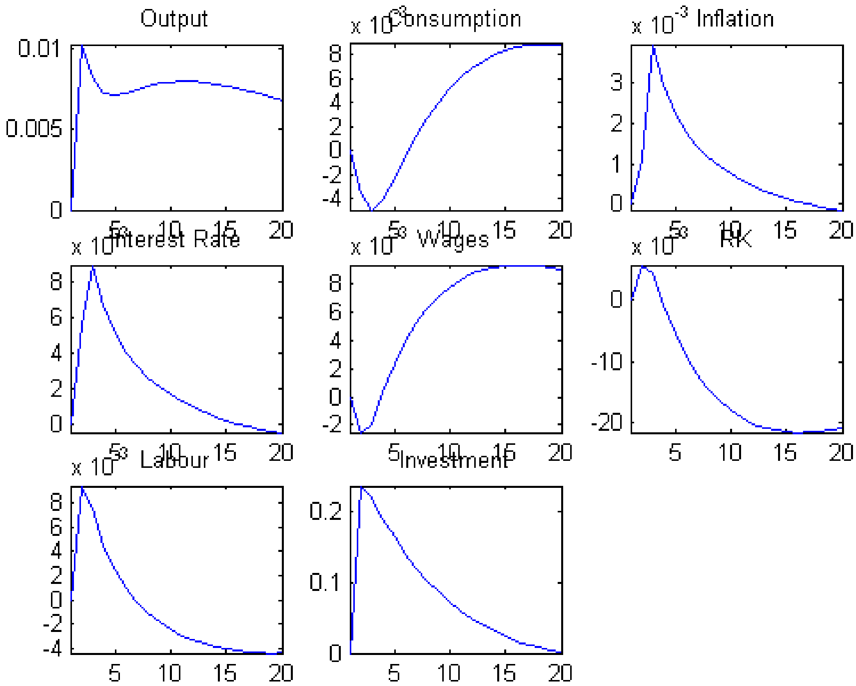

Figure 87: Investment Shock

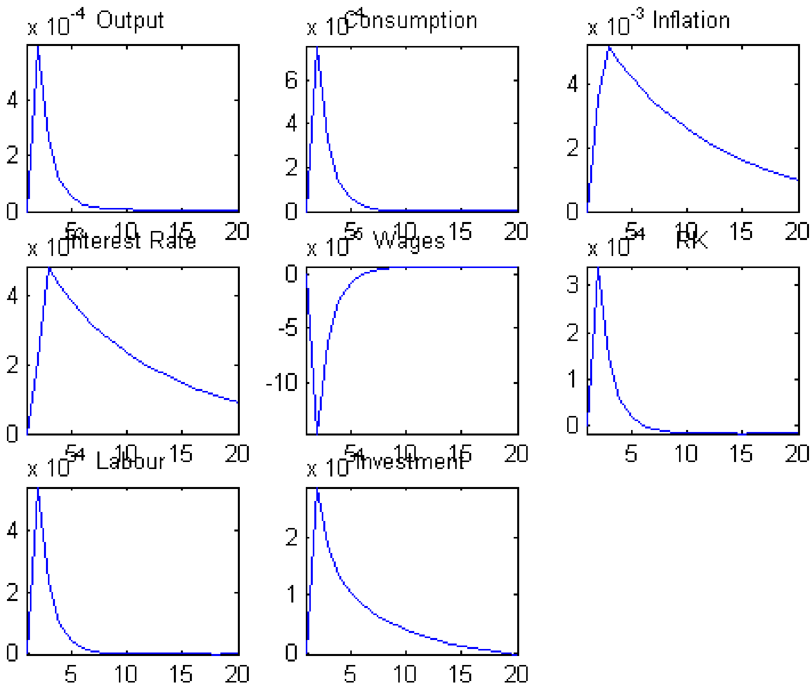

Figure 88: Price Shock

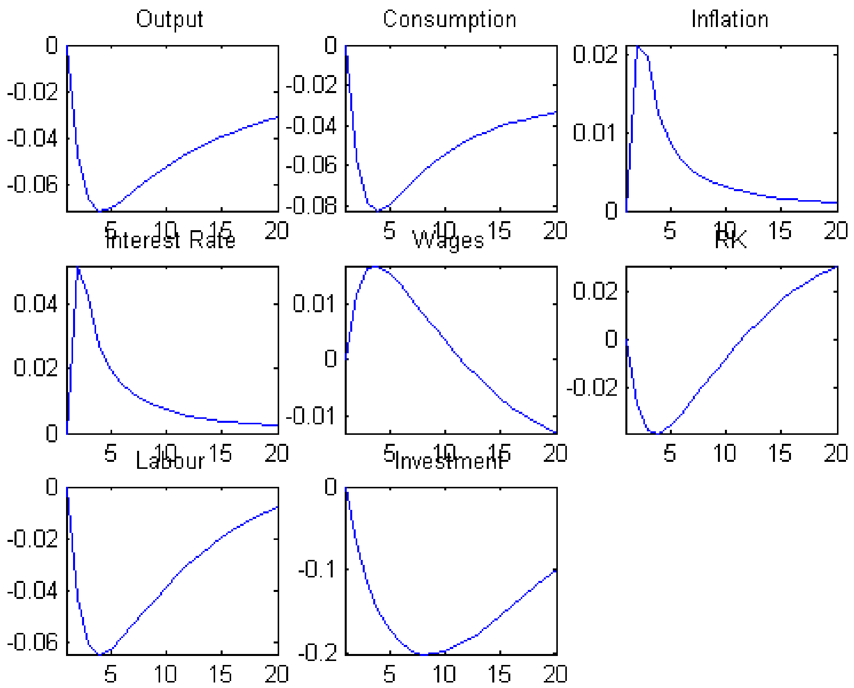

Figure 89: Wage Shock

Appendix I SW Model (re-estimated ρs) with NC Priors — scaling times 0.25 for all shocks

I.1 Randomly selected Bootstraps versus Actual Data

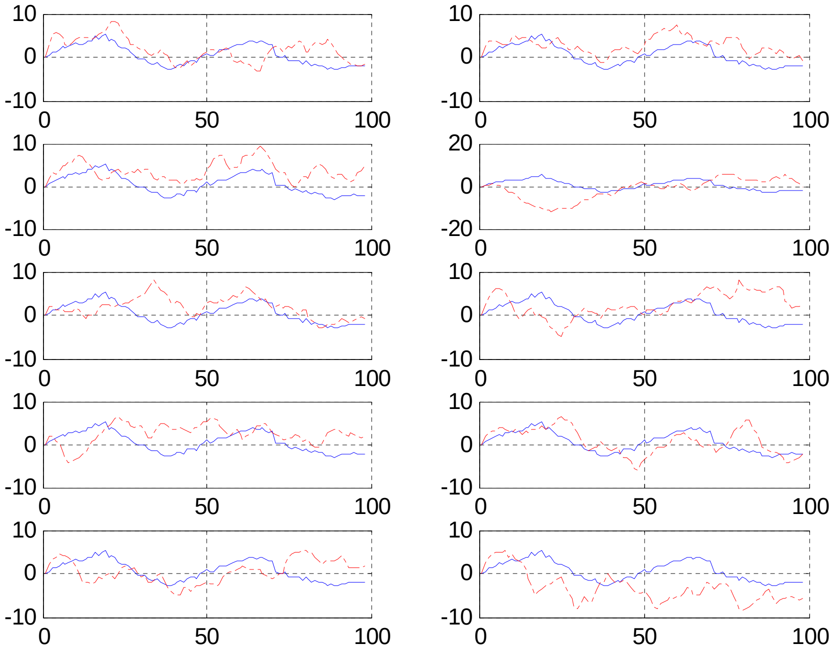

Figure 90: Consumption (Actual=blue, Simulated=red)

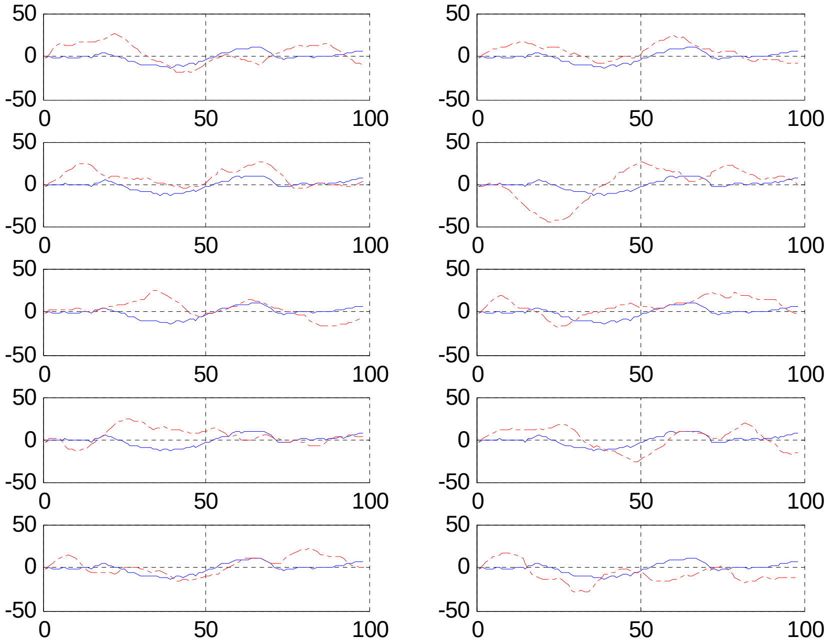

Figure 91: Investment (Actual=blue, Simulated=red)

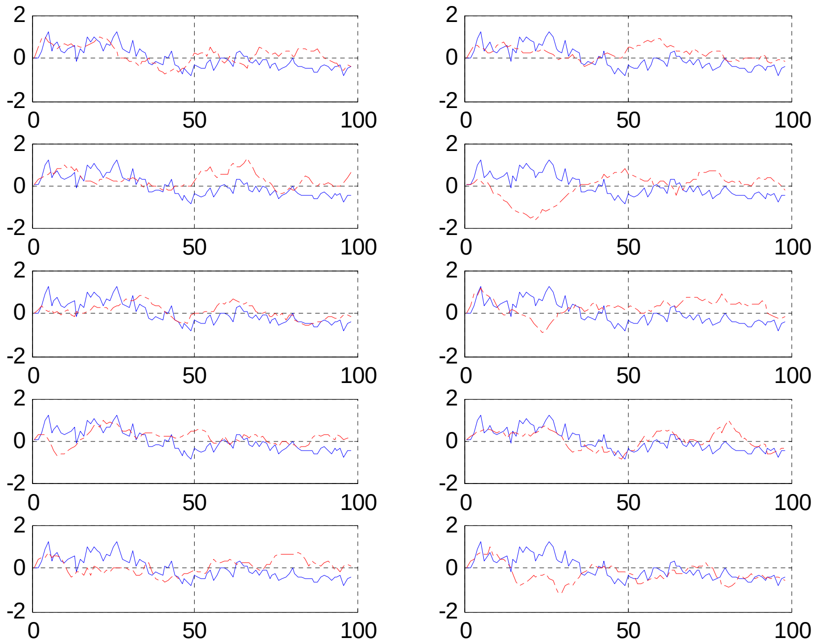

Figure 92: Inflation (Actual=blue, Simulated=red)

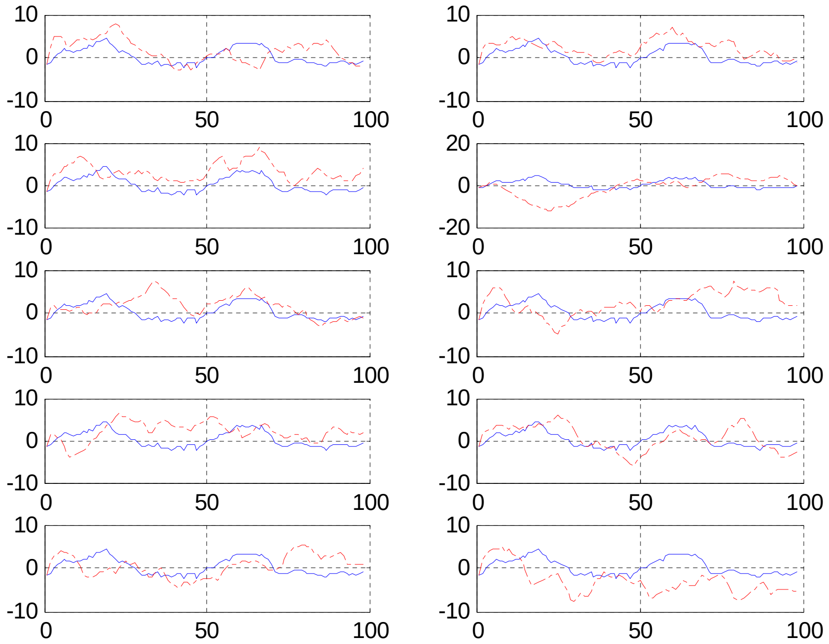

Figure 93: Output (Actual=blue, Simulated=red)

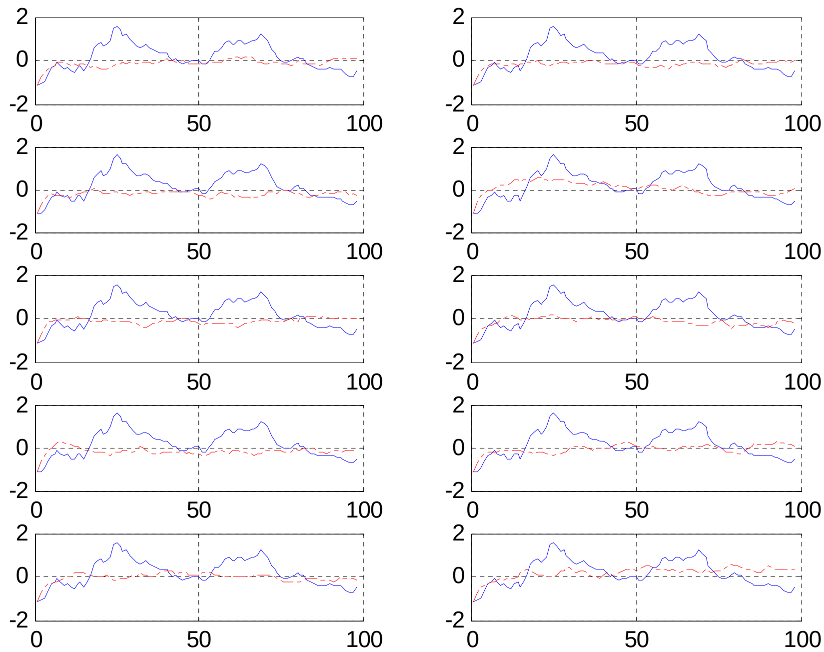

Figure 94: Interest Rate (Actual=blue, Simulated=red)

I.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

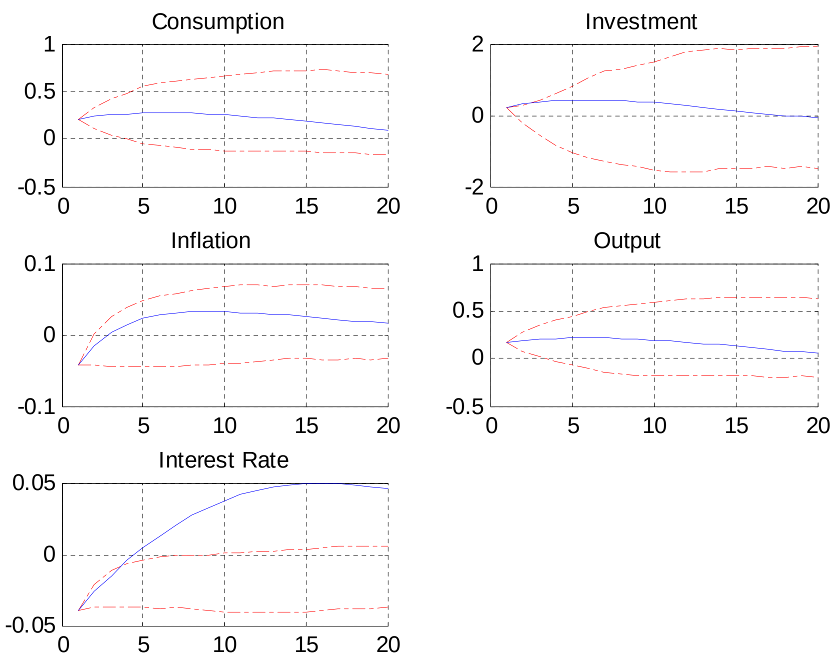

Figure 95: Productivity Shock

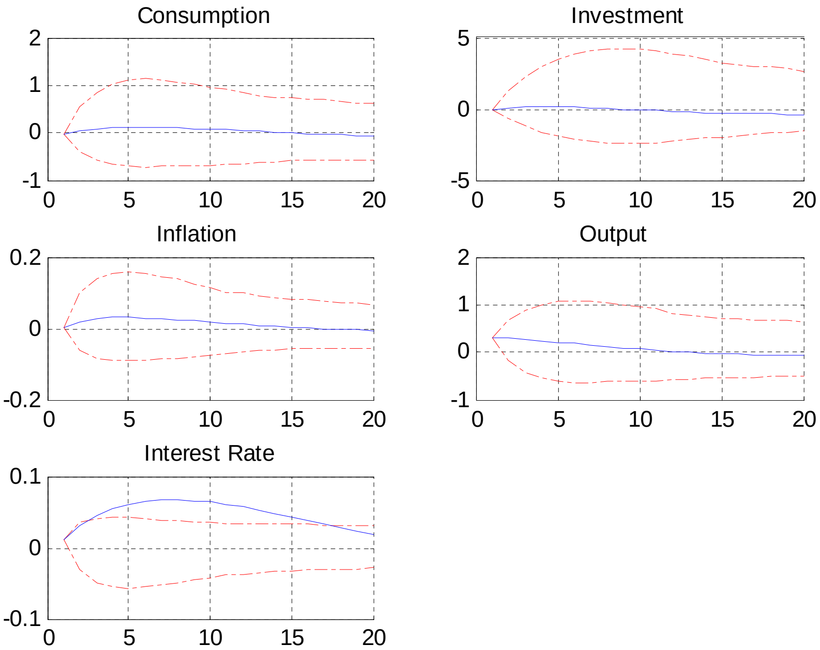

Figure 96: Government Spending Shock

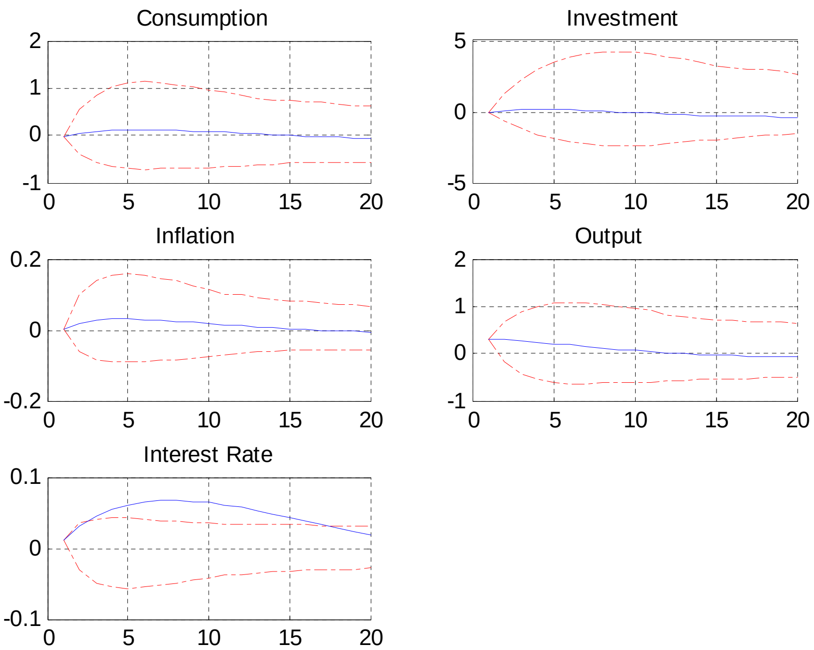

Figure 97: Price Shock

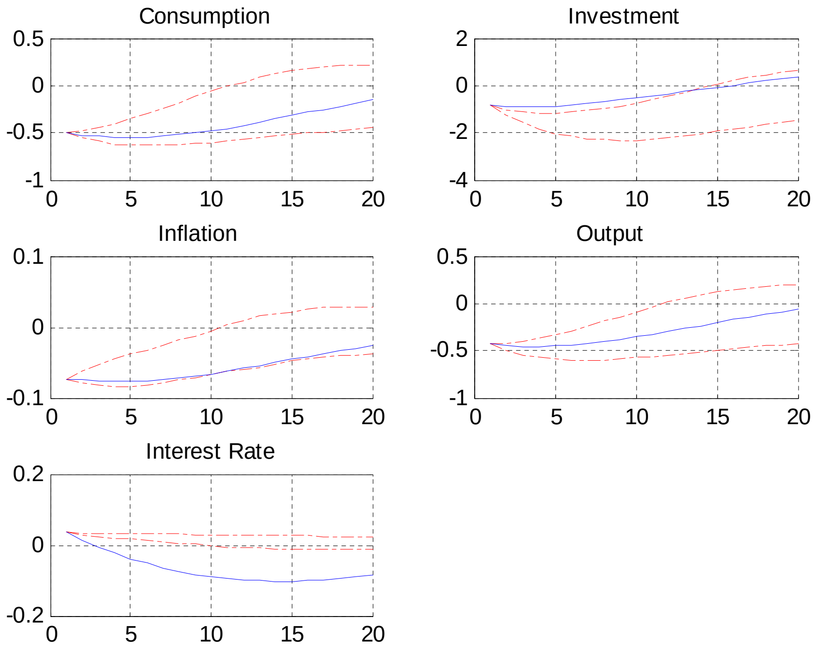

Figure 98: Monetary Shock

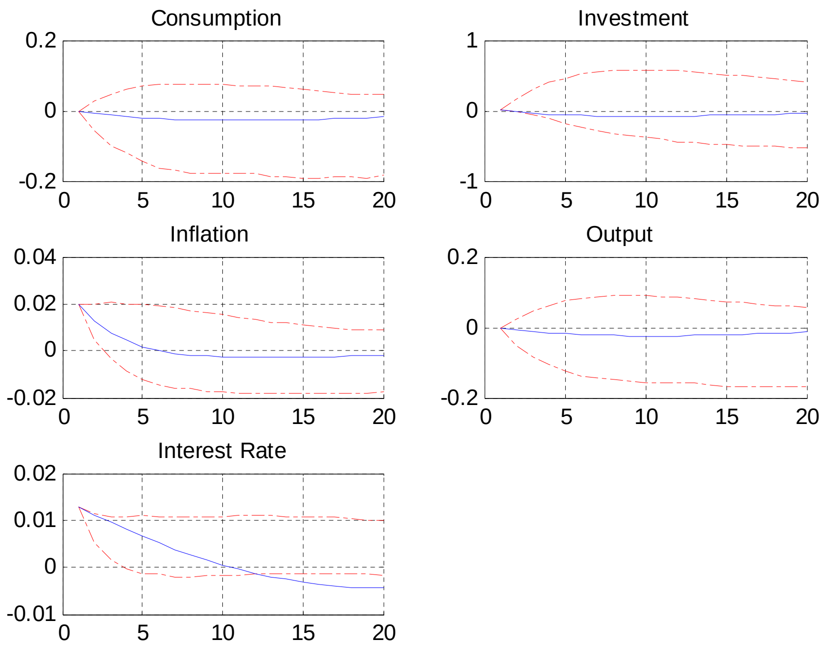

Figure 99: Wage Shock

I.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	-0.81166	1.85619	TRUE	0.525772
A_C^I	-0.09612	-3.83059	1.71681	TRUE	0.709868
A_C^π	0.01867	-0.28460	0.16062	TRUE	0.681214
A_C^Y	0.07935	-1.25562	1.13108	TRUE	0.279366
A_C^R	-0.00824	-0.10551	0.08354	TRUE	0.088087
A_I^C	-0.02461	-0.12078	0.02567	TRUE	0.526043
A_I^I	0.91856	0.60840	0.91370	FALSE	2.089366
A_I^π	-0.01074	-0.01790	0.00690	TRUE	-0.852410
A_I^Y	-0.01190	-0.08309	0.04790	TRUE	0.132191
A_I^R	-0.00504	-0.00059	0.01029	FALSE	-3.545050
A_π^C	-0.04105	-0.63293	2.07313	TRUE	-1.226070
A_π^I	-0.71538	2.31909	9.36732	FALSE	-4.087640
A_π^π	0.68194	0.53171	1.12340	TRUE	-1.358600
A_π^Y	-0.00692	-0.32848	2.14623	TRUE	-1.613530
A_π^R	-0.01605	-0.09251	0.09916	TRUE	-0.425590
A_Y^C	0.21989	-1.08178	1.85881	TRUE	-0.218320
A_Y^I	0.38855	-2.07866	4.05922	TRUE	-0.427270
A_Y^π	0.05457	-0.18196	0.32477	TRUE	-0.104710
A_Y^Y	0.93795	-0.48995	2.17975	TRUE	0.105887
A_Y^R	0.06281	-0.12303	0.08487	TRUE	1.482965
A_R^C	-0.37666	-4.37150	0.27673	TRUE	1.446385
A_R^I	-0.97612	-8.07382	0.87914	TRUE	1.156372
A_R^π	-0.05704	-0.73277	-0.00625	TRUE	1.564740
A_R^Y	-0.40669	-4.30481	-0.13985	TRUE	1.795803
A_R^R	0.89695	0.44472	0.78567	FALSE	3.271842
	Wald Statistic	93.5			

*t-stat from bootstrap mean

Table 40: VAR Parameters & Model Bootstrap Bounds (SW with NC Priors)

I.4 Results for SW Model with NC Priors

	Prod	Gov	Price	Int	Wage
ρ	0.940	0.751	-0.154	0.565	-0.038
Var	0.784	0.324	0.061	1.094	0.270

Table 41: AR Coefficients and Variances of Shocks for SW Model with estimated rhos and NC Priors

	Full varcovar	Just variances
VAR(1)	100	93.5

Table 42: Wald statistics for SW Model with estimated rhos and NC Priors

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	3.5347	41.9723	0.0750	3.2080	0.0245
Upper	22.4341	372.7300	0.3835	21.2992	0.0810
Mean	10.0461	152.6429	0.1871	9.4483	0.0439

Table 43: Variance of Data and Bootstraps for SW Model with estimated rhos and NC Priors

	Prod	Gov	Price	Int	Wage	TOTAL
c	2.881	0.007	0.033	97.058	0.021	100
I	1.370	0.003	0.037	98.573	0.017	100
K	2.531	0.004	0.034	97.410	0.021	100
L	2.618	0.296	0.031	97.024	0.032	100
π	0.651	0.003	1.739	97.438	0.168	100
Q	0.140	0.002	0.042	99.804	0.012	100
R	6.510	0.193	0.404	92.656	0.237	100
rk	1.337	0.078	0.074	98.274	0.237	100
w	2.516	0.002	0.114	96.641	0.727	100
Y	2.570	0.196	0.034	97.180	0.020	100

Table 44: Variance Decompositon for SW Model with estimated rhos and NC Priors

I.5 Cross-Correlations for SW's Model with estimated ρs (with NC Priors)

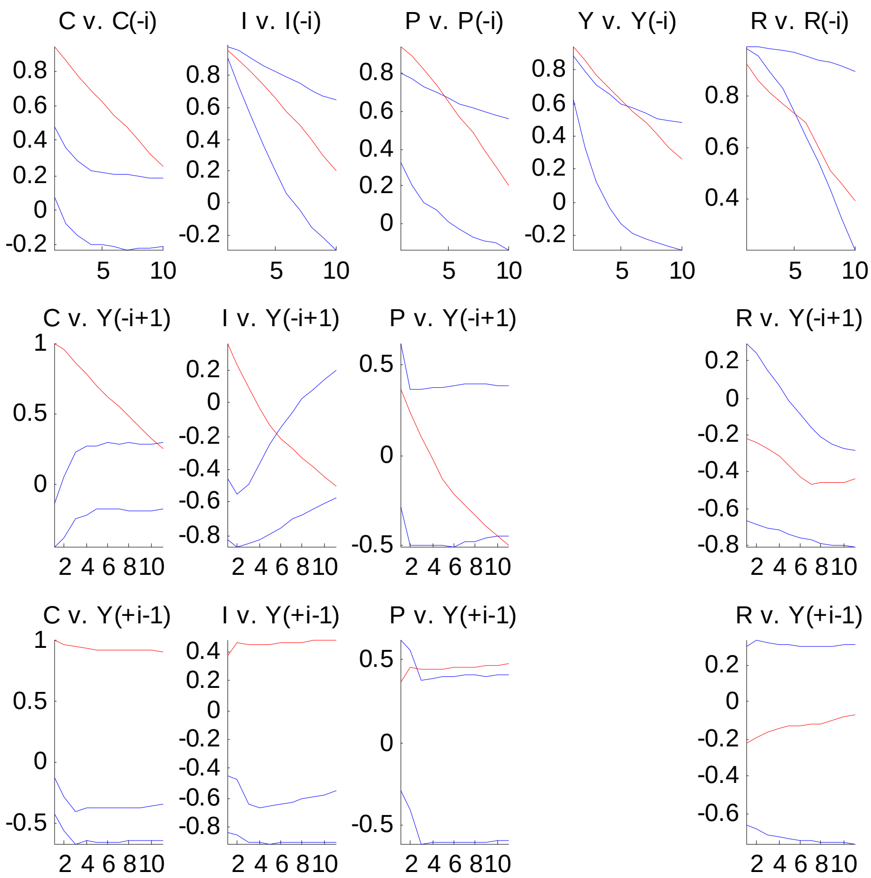

Figure 100: Cross-Correlations for SW's Model with estimated ρs (with NC Priors)

Appendix J Flexprice Version of SW's Model with NC Priors — scaling times 0.7 for all shocks

J.1 Randomly selected Bootstraps versus Actual Data

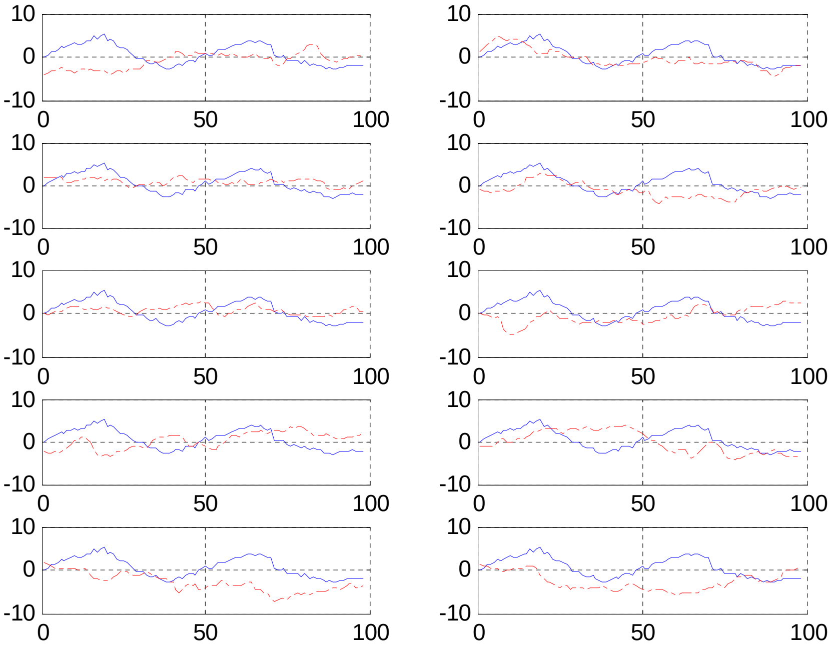

Figure 101: Consumption (Actual=blue, Simulated=red)

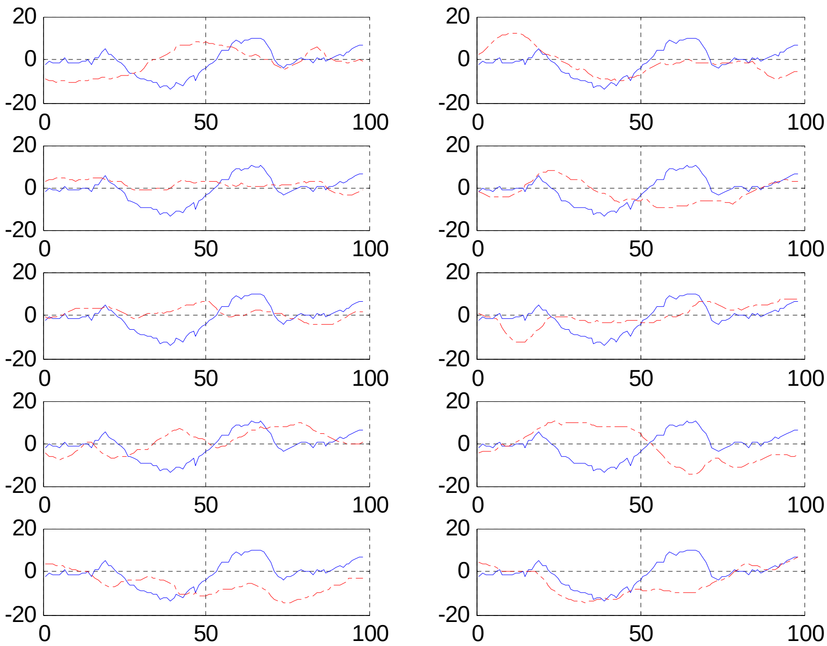

Figure 102: Investment (Actual=blue, Simulated=red)

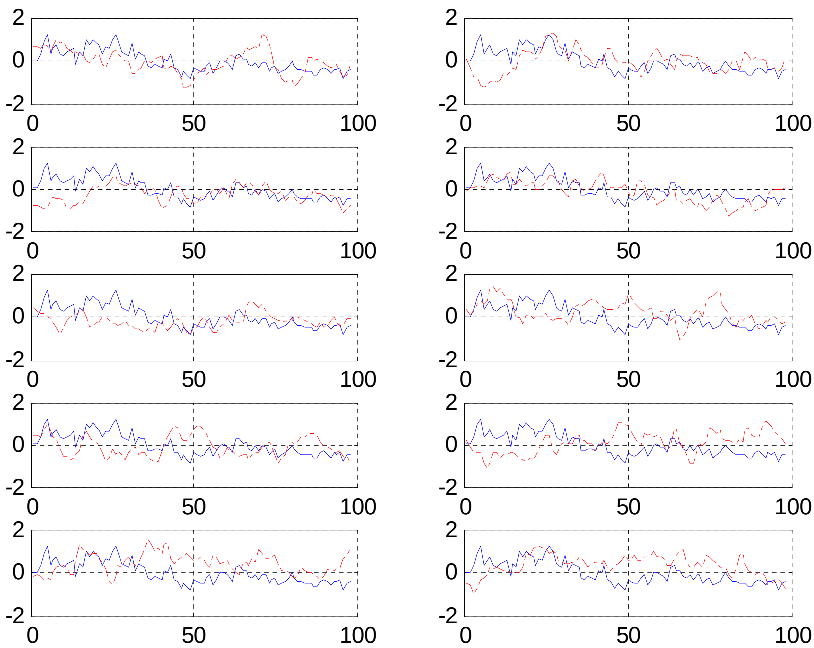

Figure 103: Inflation (Actual=blue, Simulated=red)

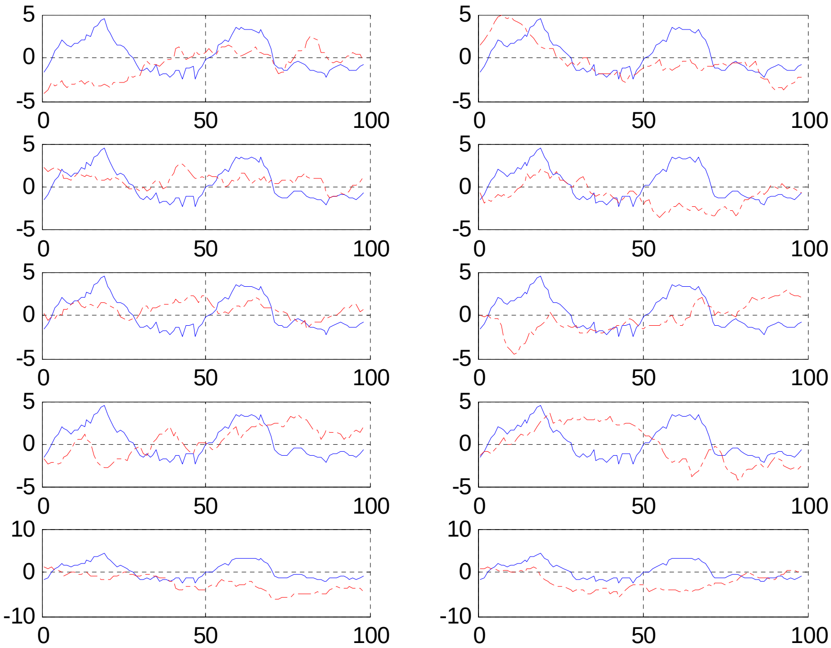

Figure 104: Output (Actual=blue, Simulated=red)

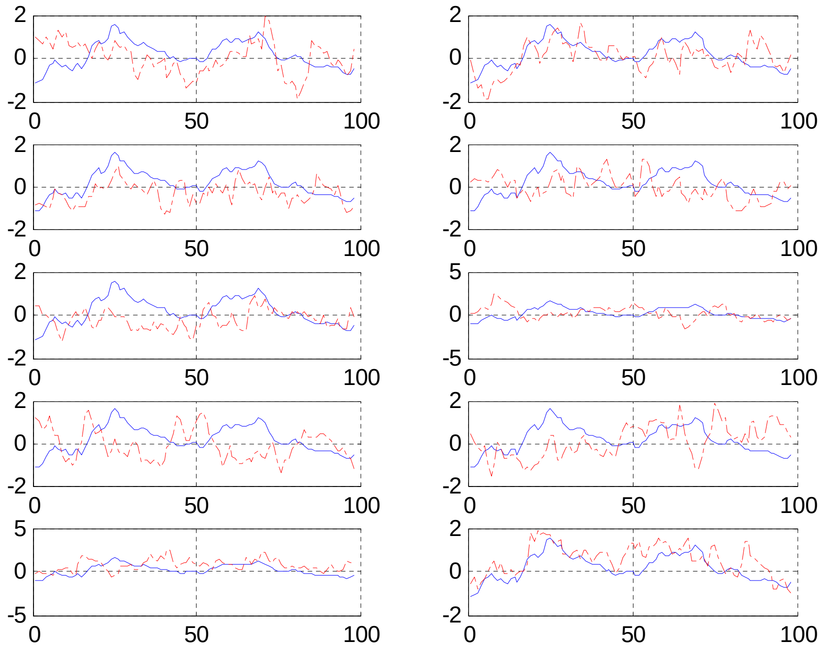

Figure 105: Interest Rate (Actual=blue, Simulated=red)

J.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

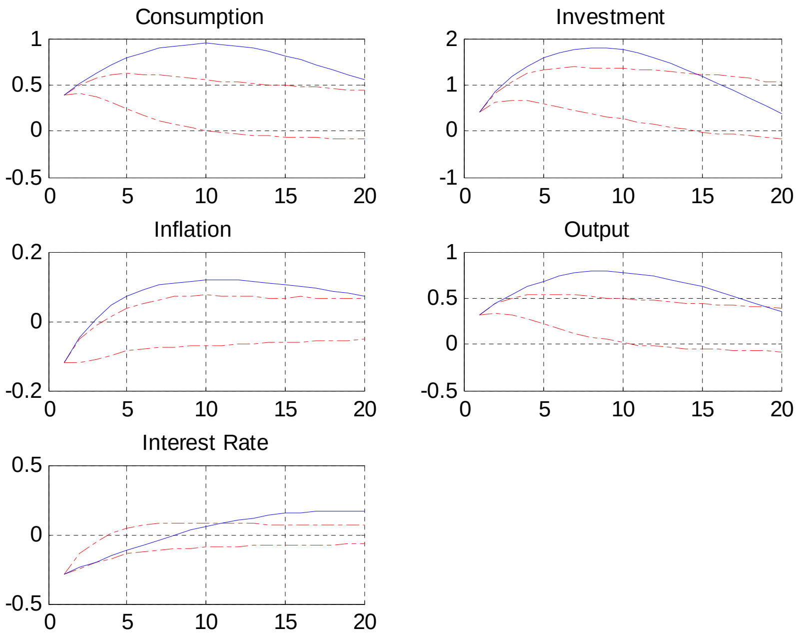

Figure 106: Productivity Shock

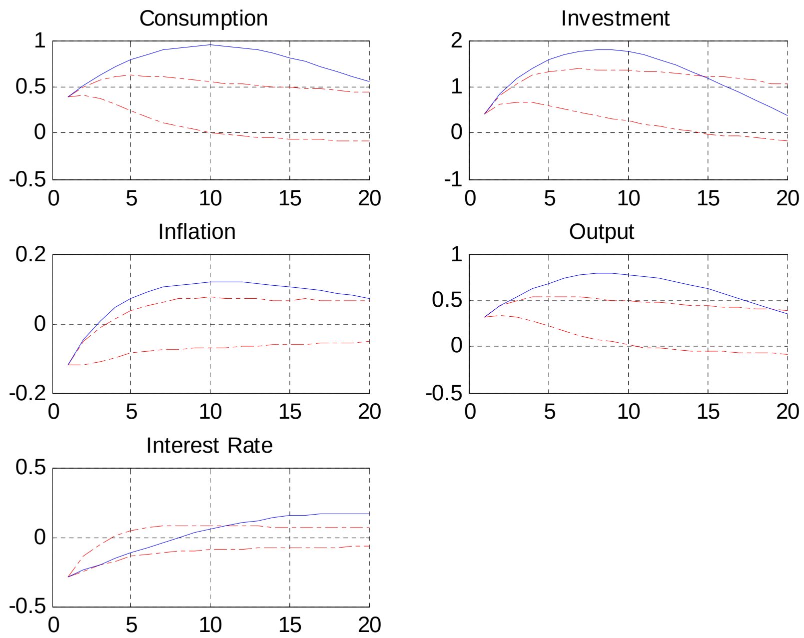

Figure 107: Government Spending Shock

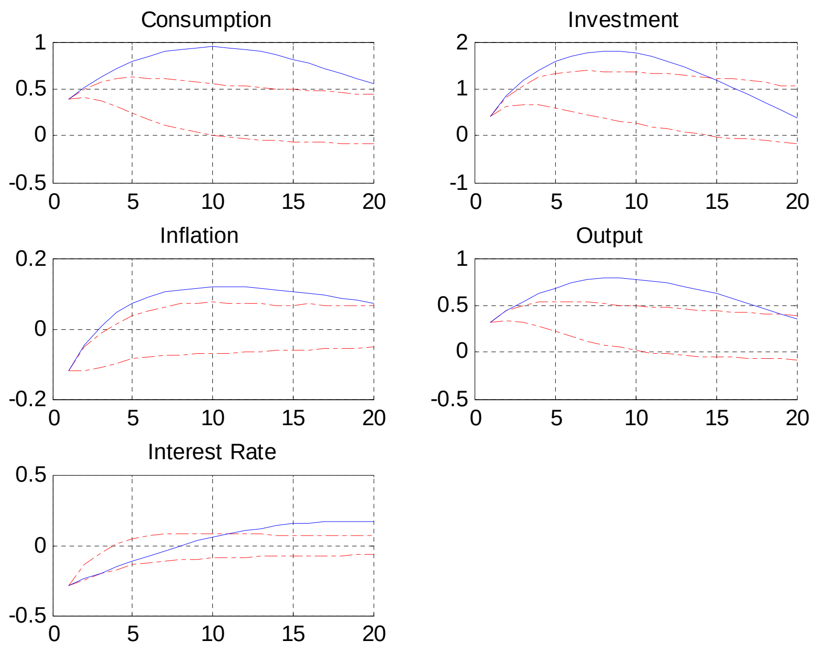

Figure 108: Price Shock

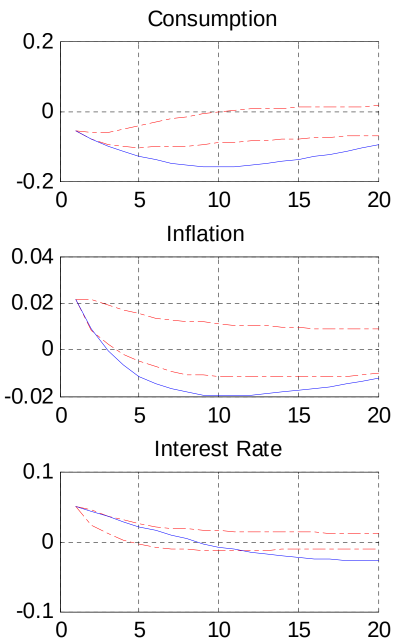

Figure 109: Wage Shock

J.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.38922	1.00516	TRUE	0.995288
A_C^I	-0.09612	-0.83115	0.13808	TRUE	1.112782
A_C^π	0.01867	-0.15051	0.22081	TRUE	-0.091270
A_C^Y	0.07935	-0.31773	0.33397	TRUE	0.428828
A_C^R	-0.00824	-0.25663	0.33100	TRUE	-0.245590
A_I^C	-0.02461	-0.06432	0.06105	TRUE	-0.607980
A_I^I	0.91856	0.84056	1.02208	TRUE	-0.432470
A_I^π	-0.01074	-0.03590	0.03334	TRUE	-0.585580
A_I^Y	-0.01190	-0.04825	0.07188	TRUE	-0.704740
A_I^R	-0.00504	-0.05913	0.05865	TRUE	-0.190610
A_π^C	-0.04105	-0.11680	1.21684	TRUE	-1.873900
A_π^I	-0.71538	0.39292	2.45209	FALSE	-4.109700
A_π^π	0.68194	0.59311	1.31572	TRUE	-1.560290
A_π^Y	-0.00692	-0.13882	1.09768	TRUE	-1.627570
A_π^R	-0.01605	-0.27846	1.01944	TRUE	-1.155630
A_Y^C	0.21989	-0.09905	0.43690	TRUE	0.370253
A_Y^I	0.38855	-0.03180	0.76454	TRUE	0.123248
A_Y^π	0.05457	-0.18409	0.13951	TRUE	0.906083
A_Y^Y	0.93795	0.54713	1.06406	TRUE	0.811690
A_Y^R	0.06281	-0.30796	0.22601	TRUE	0.673076
A_R^C	-0.37666	-1.23808	-0.19850	TRUE	1.199080
A_R^I	-0.97612	-2.70167	-0.90465	TRUE	1.847340
A_R^π	-0.05704	-0.40124	0.21020	TRUE	0.216398
A_R^Y	-0.40669	-1.12134	-0.07573	TRUE	0.805590
A_R^R	0.89695	0.02191	1.00569	TRUE	1.414609
	Wald Statistic	85.0			

*t-stat from bootstrap mean

Table 45: VAR Parameters & Model Bootstrap Bounds for Flex-price Model with NC Priors)

J.4 Results for Flex-Price Model with NC Priors

	Prod	Gov	Price	Int	Wage
ρ	0.940	0.751	0.909	0.565	0.905
Var	0.784	0.324	0.510	0.900	25.021

Table 46: AR Coefficients and Variances of Shocks for Flex-Price Model with NC Priors

	Full varcovar	Just variances	Direct vars/Actual covars
VAR(1)	100	85.0	87.6

Table 47: Wald statistics for Flex-Price Model with NC Priors

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	0.6578	4.8250	0.0986	0.5769	0.1910
Upper	6.4263	56.6121	0.3985	5.3142	0.6991
Mean	2.3265	20.6644	0.2055	1.9926	0.3864

Table 48: Variance of Data and Bootstraps for Flex-Price Model with NC Priors

	Prod	Gov	Price	Wage	TOTAL
c	35.621	0.388	0.032	63.959	100
I	30.511	0.24	0.001	69.248	100
K	36.036	0.141	0	63.823	100
L	25.702	2.225	0.046	72.026	100
π	2.543	0.643	84.751	12.064	100
Q	18.231	1.804	0.759	79.206	100
R	8.928	2.185	46.138	42.749	100
rk	32.623	0.686	0.01	66.681	100
w	83.989	0.163	0.002	15.846	100
$E_{t-1}\pi_t$	1.79	0.412	89.112	8.686	100
Y	34.674	1.19	0.025	64.111	100

Table 49: Variance Decompositon for Flex Model with NC Priors

J.5 Cross-Correlations for Flex-Price Model (with NC Priors)

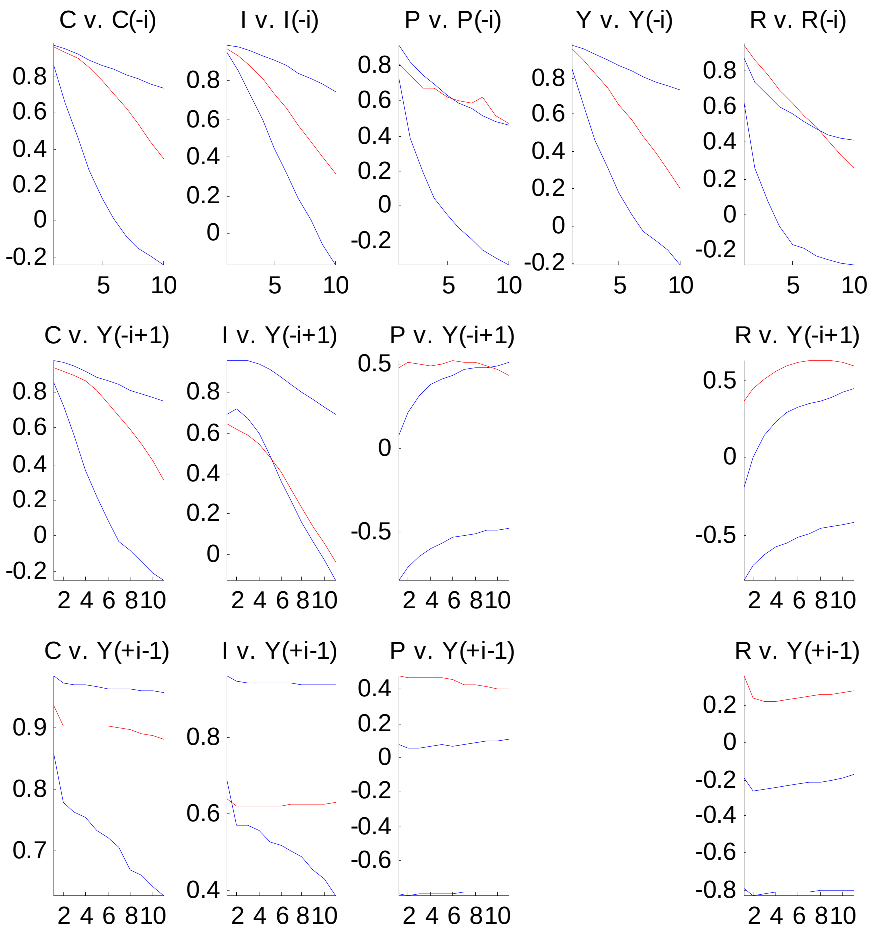

Figure 110: Cross-Correlations for Flex-Price Model (with NC Priors)

Appendix K SW Model (re-estimated ρs) using HP filtered — scaling times 0.2 for all shocks

K.1 Randomly selected Bootstraps versus Actual Data

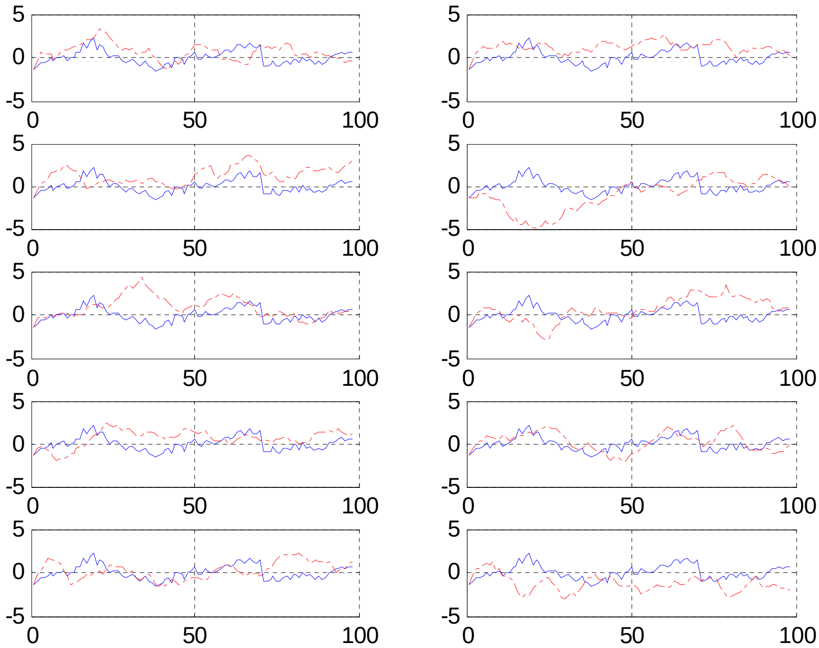

Figure 111: Consumption (Actual=blue, Simulated=red)

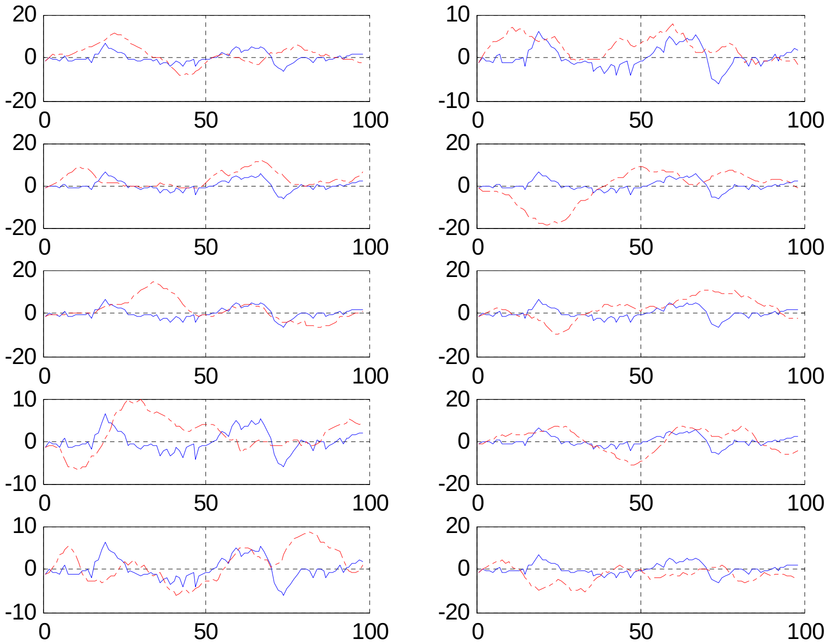

Figure 112: Investment (Actual=blue, Simulated=red)

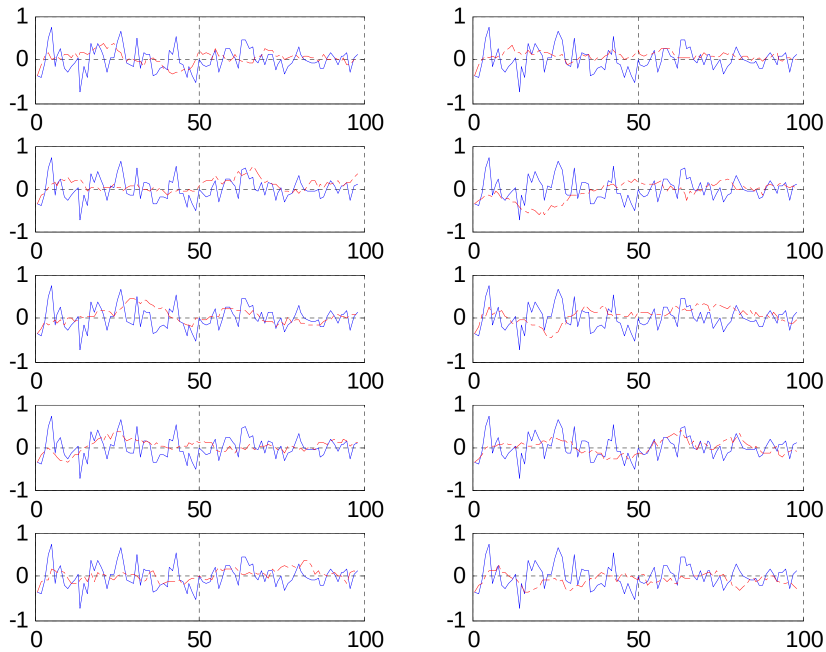

Figure 113: Inflation (Actual=blue, Simulated=red)

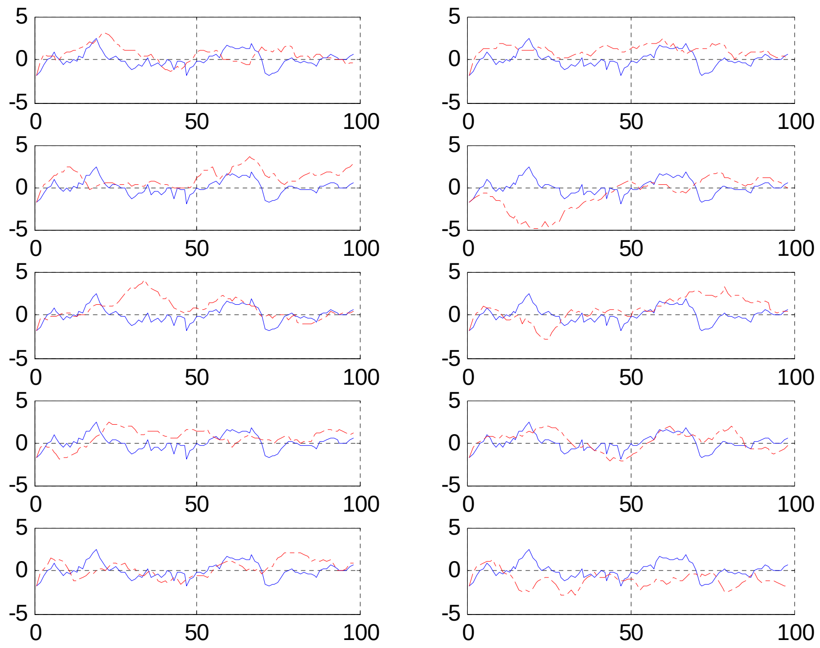

Figure 114: Output (Actual=blue, Simulated=red)

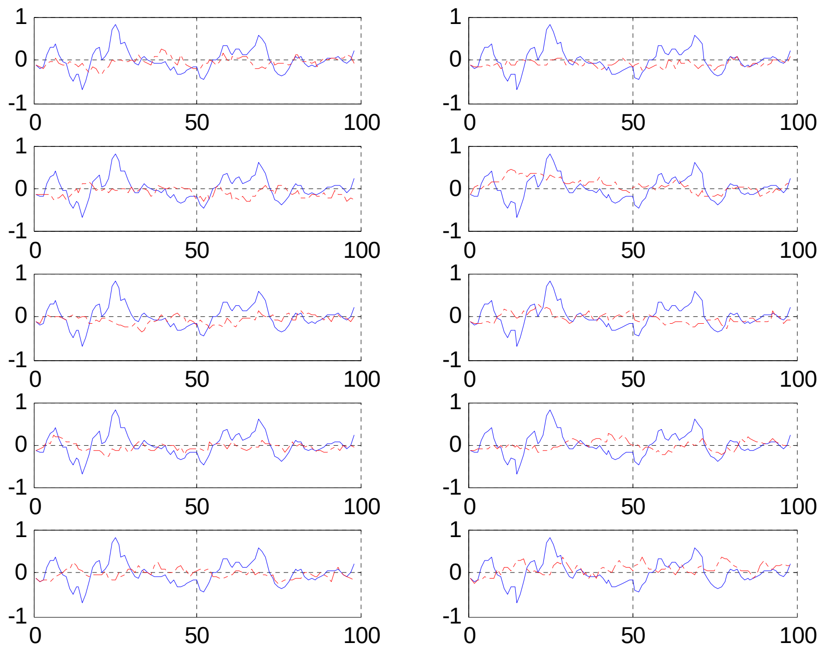

Figure 115: Interest Rate (Actual=blue, Simulated=red)

K.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

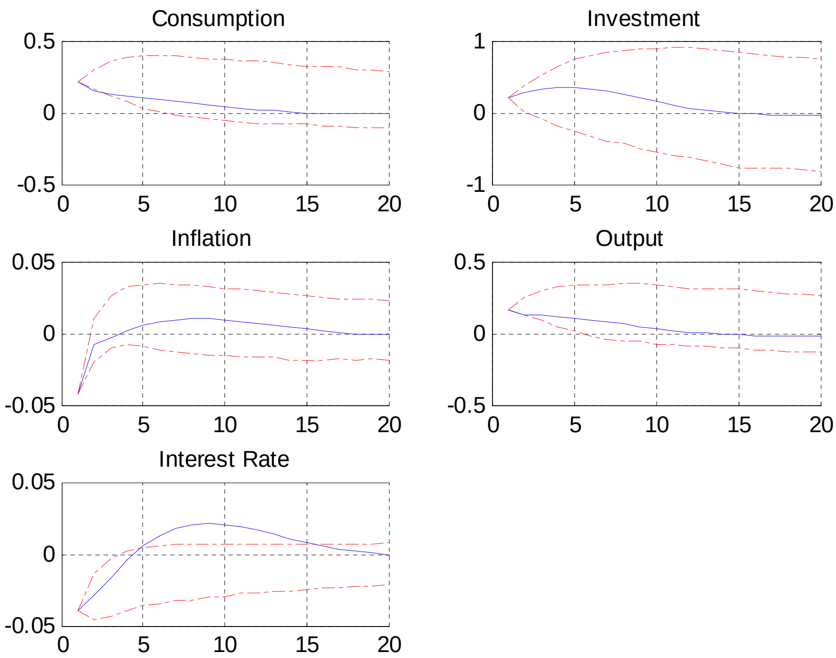

Figure 116: Productivity Shock

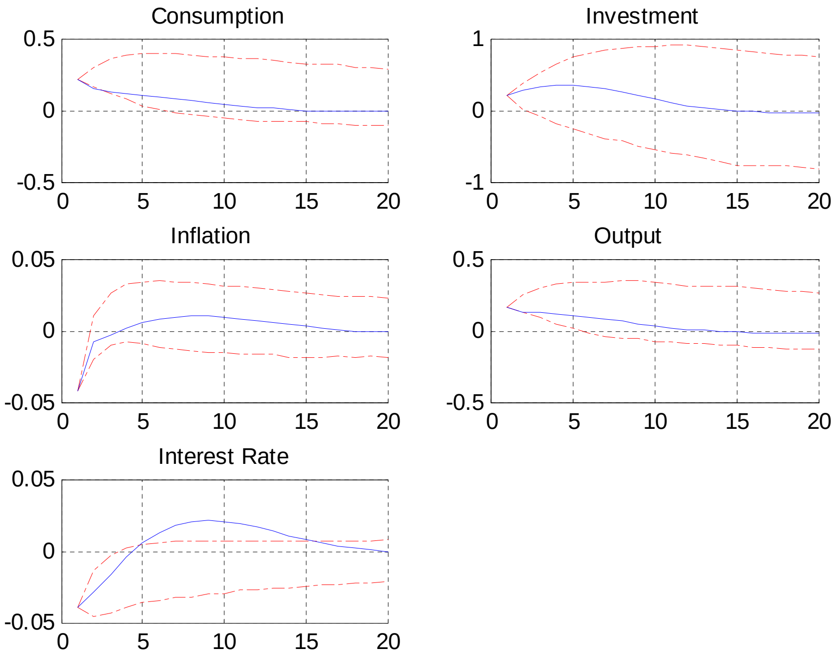

Figure 117: Consumer Preference Shock

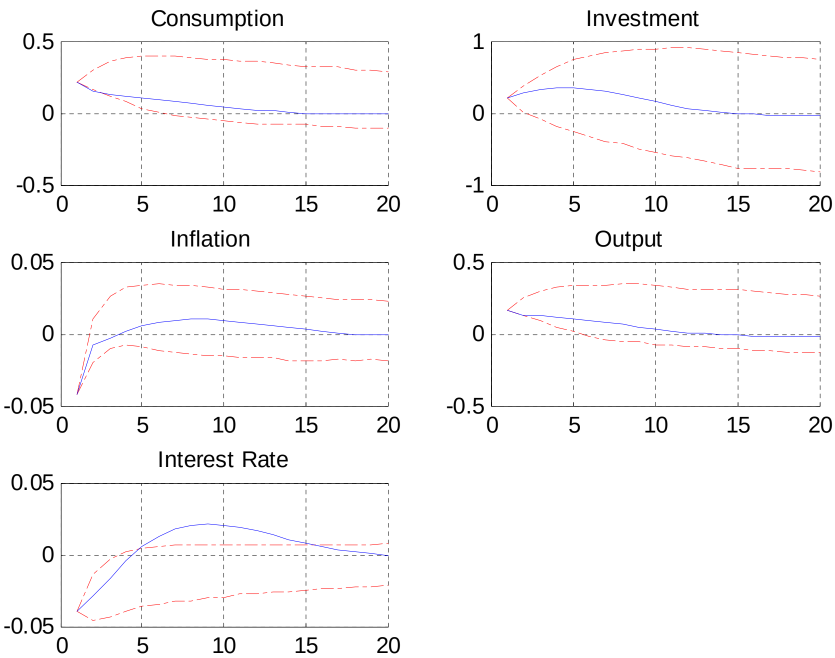

Figure 118: Government Spending Shock

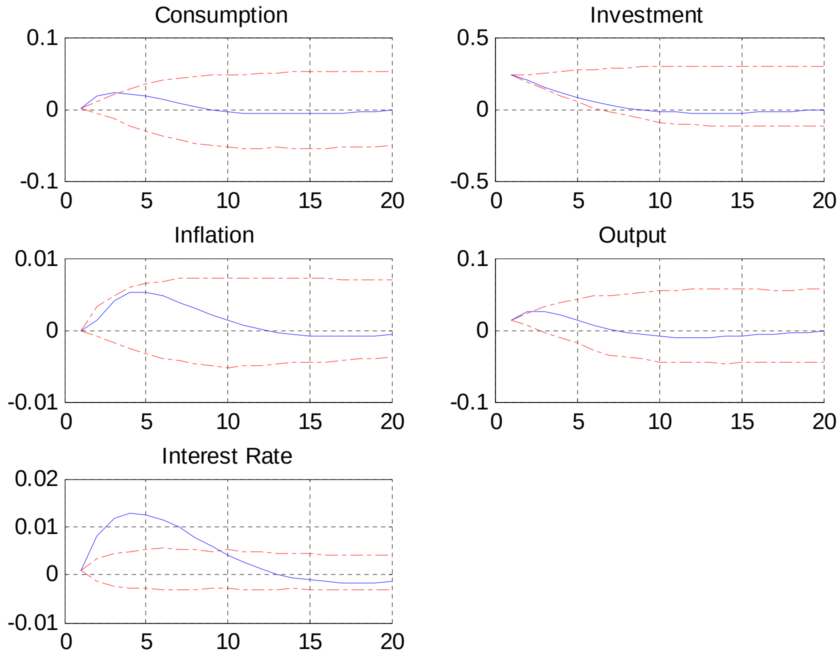

Figure 119: Investment Shock

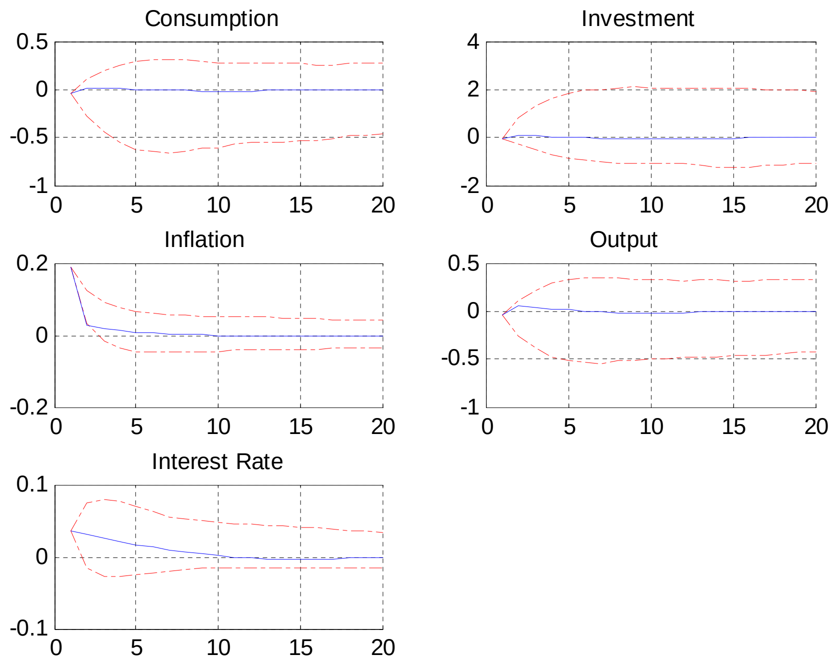

Figure 120: Price Shock

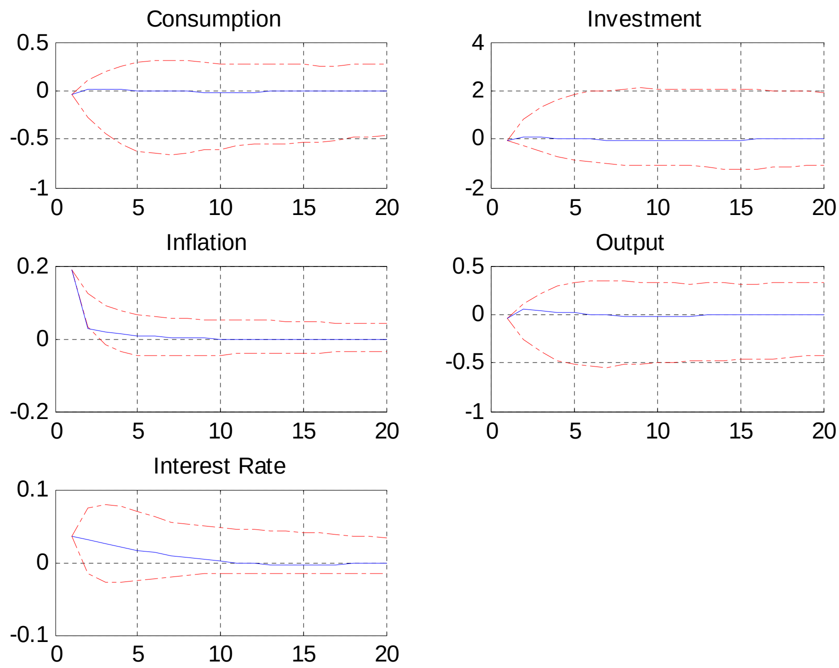

Figure 121: Monetary Shock

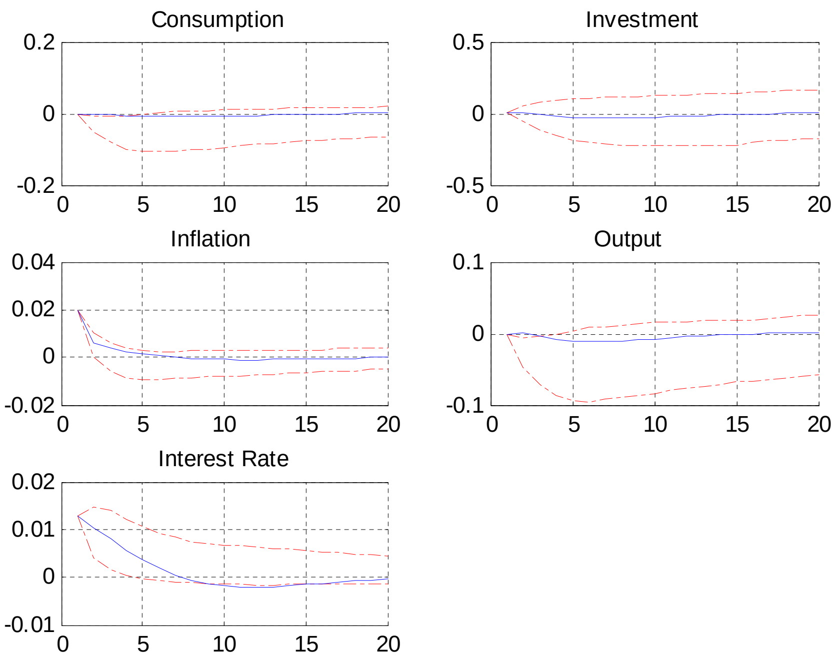

Figure 122: Wage Shock

K.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.599104	0.179799	1.310040	TRUE	-0.6007
A_C^I	0.200354	-1.489360	1.415612	TRUE	0.3915
A_C^π	-0.036330	-0.128250	0.104386	TRUE	-0.4512
A_C^Y	-0.075580	-0.308830	0.799480	TRUE	-1.1321
A_C^R	-0.034110	-0.155190	0.106427	TRUE	-0.1681
A_I^C	0.070076	-0.028230	0.068875	FALSE	2.0630
A_I^I	0.808143	0.799829	1.065858	TRUE	-1.9099
A_I^π	-0.000310	-0.005840	0.015745	TRUE	-1.1511
A_I^Y	0.070233	0.004045	0.102682	TRUE	0.8036
A_I^R	0.031282	-0.011310	0.012869	FALSE	5.0526
A_π^C	0.341526	-0.862450	1.158588	TRUE	0.5653
A_π^I	1.368568	-0.134450	5.485296	TRUE	-0.9663
A_π^π	0.104010	0.236261	0.738530	FALSE	-3.0996
A_π^Y	0.615050	-0.796520	1.162290	TRUE	0.9767
A_π^R	0.032077	-0.222390	0.258522	TRUE	0.0670
A_Y^C	0.064817	-0.780280	0.605913	TRUE	0.4536
A_Y^I	0.244827	-2.156810	1.343379	TRUE	0.7347
A_Y^π	0.088443	-0.125860	0.139818	TRUE	1.1236
A_Y^Y	0.736870	-0.336360	0.990934	TRUE	1.2519
A_Y^R	0.010331	-0.141720	0.183179	TRUE	-0.1057
A_R^C	-0.493880	-3.144700	-1.532380	FALSE	4.4957
A_R^I	-2.136870	-7.270510	-2.560320	FALSE	2.4154
A_R^π	0.281054	-0.555850	-0.144590	FALSE	6.6532
A_R^Y	-0.850080	-3.098660	-1.472150	FALSE	3.5453
A_R^R	0.724781	0.490734	0.906691	TRUE	0.0529
	Wald Statistic	99.9			

*t-stat from bootstrap mean

Table 50: VAR Parameters & Model Bootstrap Bounds (SW with HP Filtered Data)

K.4 Results for SW Model with HP filtered data

	Prod	Cons	Gov	Inv	Price	Int	Wage
ρ	0.616	-0.191	0.685	-0.061	-0.199	0.188	-0.165
Var	0.163	0.201	0.226	1.334	0.054	0.411	0.208

Table 51: AR Coefficients and Variances of Shocks for SW Model with estimated rhos and HP filtered data

	Full varcovar	Just variances
VAR(1)	100	99.9

Table 52: Wald statistics for SW Model with estimated rhos and HP filtered data

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	0.6722	6.3606	0.0674	0.7942	0.0722
Lower	0.4678	5.4524	0.0109	0.4351	0.0075
Upper	2.7828	47.6653	0.0442	2.7411	0.0232
Mean	1.2507	20.0296	0.0233	1.2277	0.0137

Table 53: Variance of Data and Bootstraps for SW Model with estimated rhos and HP filtered data

	Prod	Cons	Gov	Inv	Price	Int	Wage	TOTAL
c	0.051	0.840	0.020	0.252	0.208	98.544	0.084	100
I	0.030	0.001	0.009	2.758	0.237	96.896	0.070	100
K	0.033	0.001	0.011	1.763	0.225	97.877	0.090	100
L	1.846	0.797	1.419	0.273	0.186	95.354	0.124	100
π	0.066	0.010	0.010	0.044	11.183	88.028	0.657	100
Q	0.047	0.021	0.008	0.287	0.233	99.362	0.041	100
R	0.972	1.693	0.274	0.182	0.776	95.798	0.304	100
rk	0.446	0.238	0.375	1.132	0.468	96.307	1.035	100
w	0.013	0.013	0.006	0.274	0.749	95.659	3.286	100
Y	0.046	0.558	0.985	0.346	0.213	97.771	0.081	100

Table 54: Variance Decompositon for SW Model with estimated rhos and HP filtered data

K.5 Cross-Correlations for SW's Model with estimated ρs (with HP filtered data)

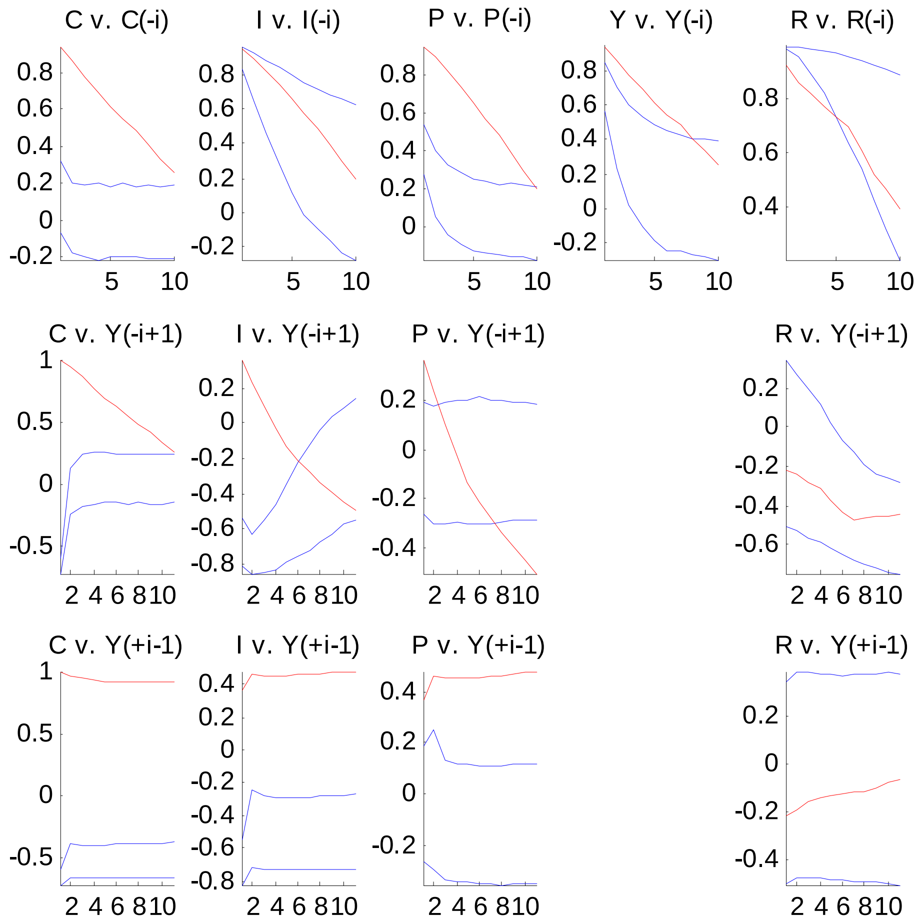

Figure 123: Cross-Correlations for SW's Model with estimated ρs (with HP filtered data)

Appendix L Flexprice Version of SW's Model with HP Filtered Data — scaling times 0.28 for all shocks

L.1 Randomly selected Bootstraps versus Actual Data

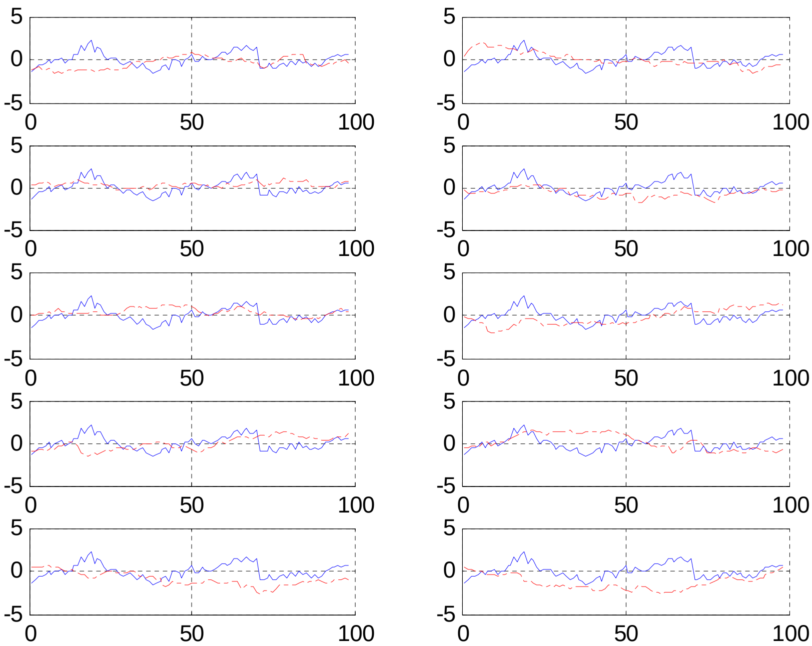

Figure 124: Consumption (Actual=blue, Simulated=red)

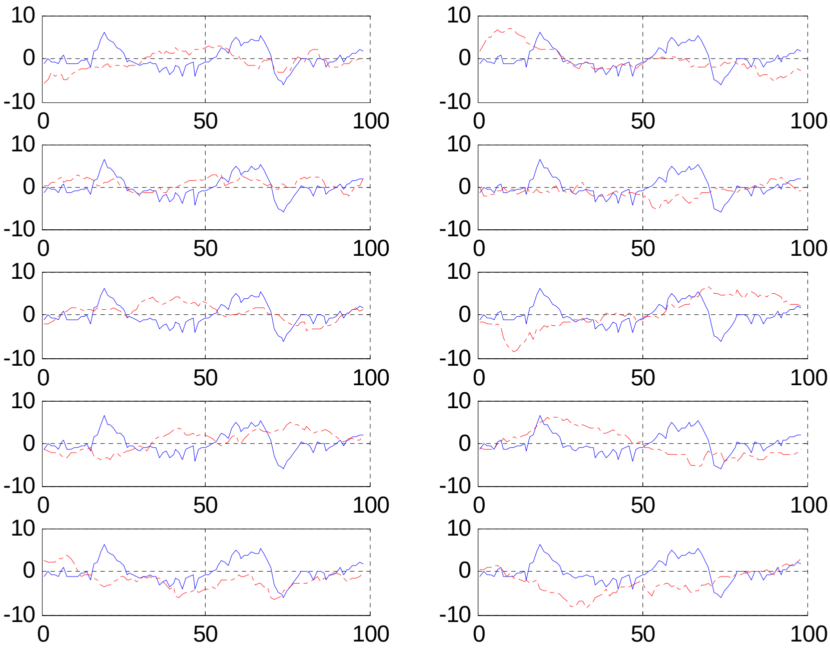

Figure 125: Investment (Actual=blue, Simulated=red)

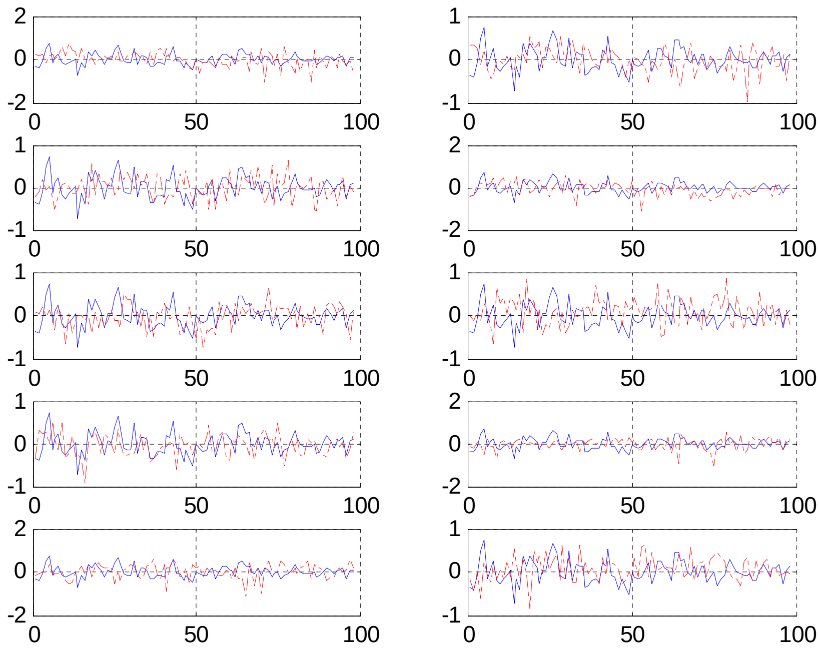

Figure 126: Inflation (Actual=blue, Simulated=red)

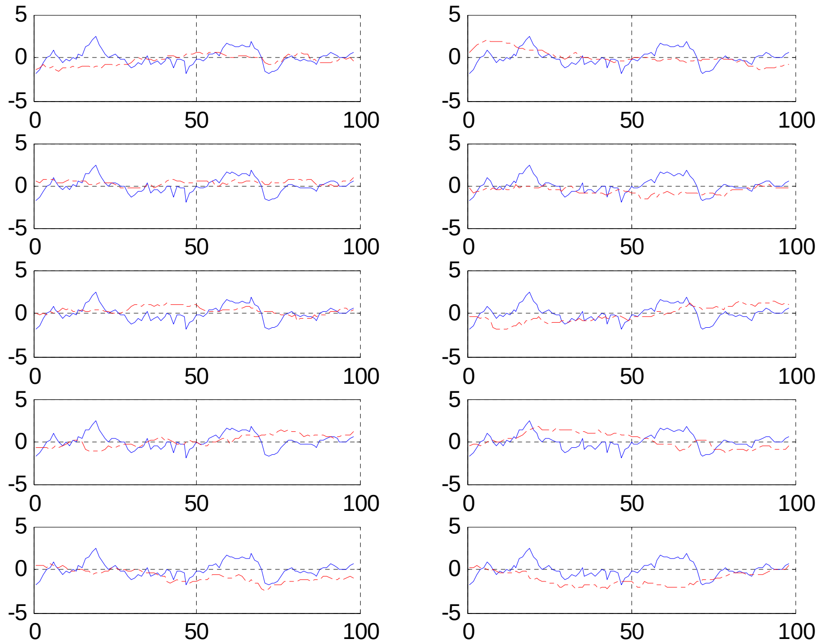

Figure 127: Output (Actual=blue, Simulated=red)

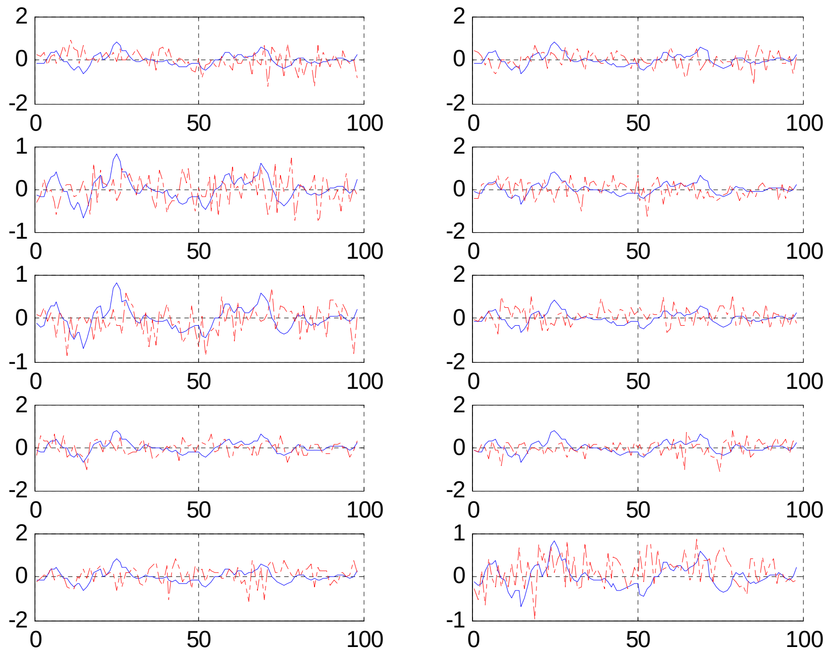

Figure 128: Interest Rate (Actual=blue, Simulated=red)

L.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

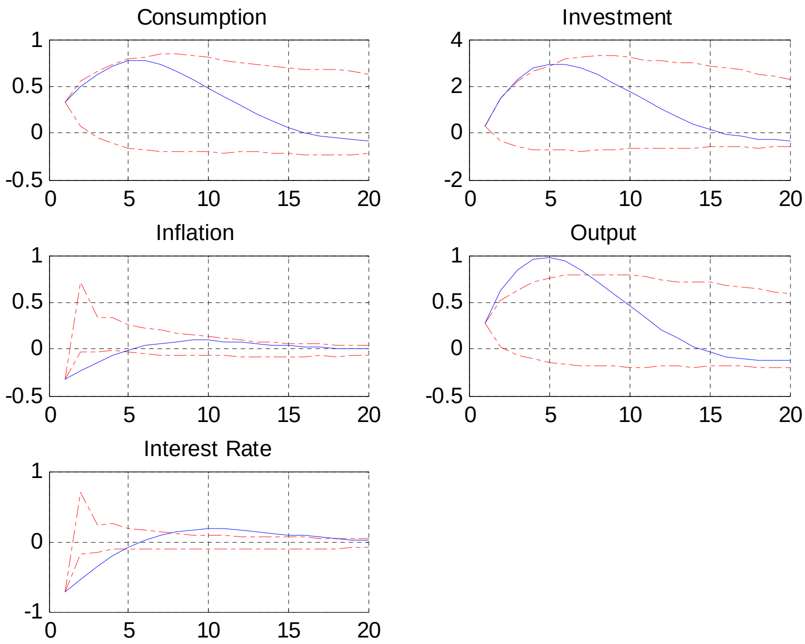

Figure 129: Productivity Shock

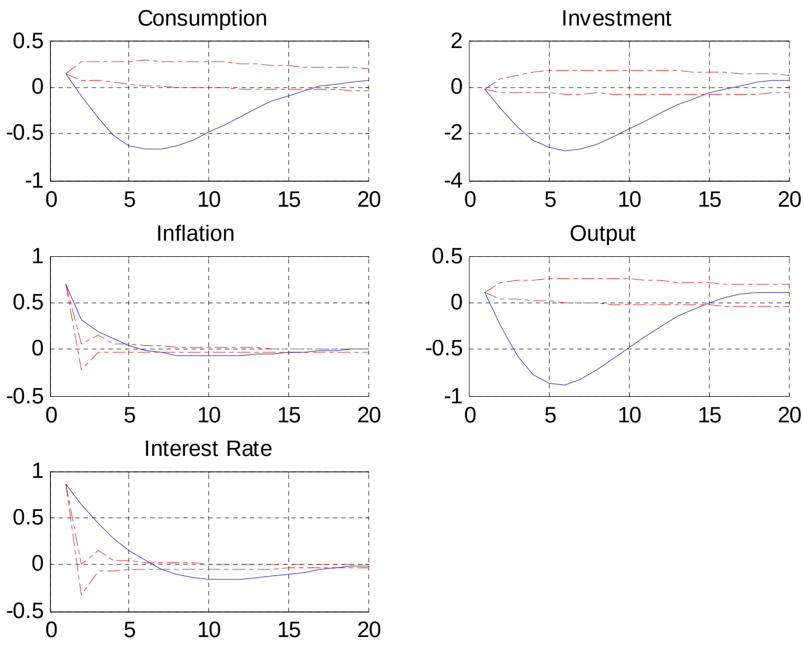

Figure 130: Consumer Preference Shock

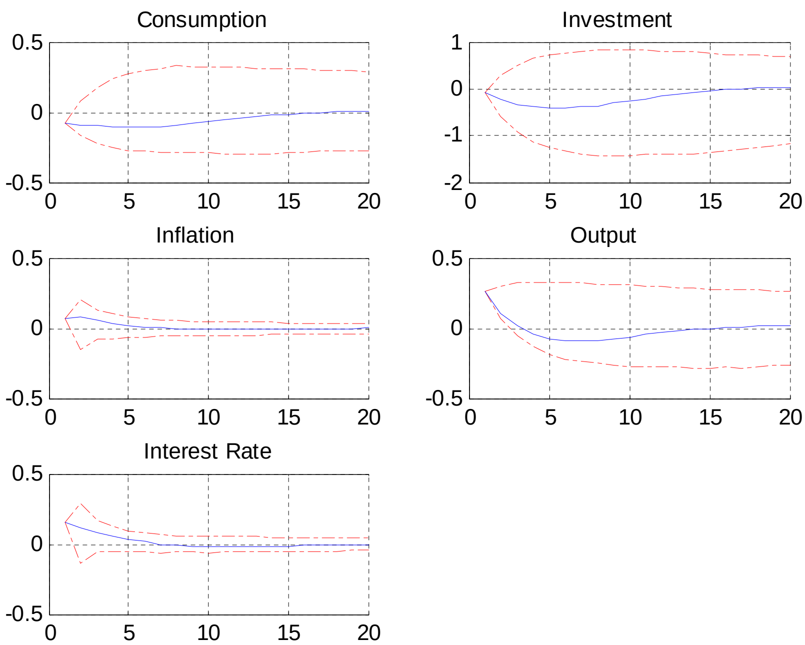

Figure 131: Government Spending Shock

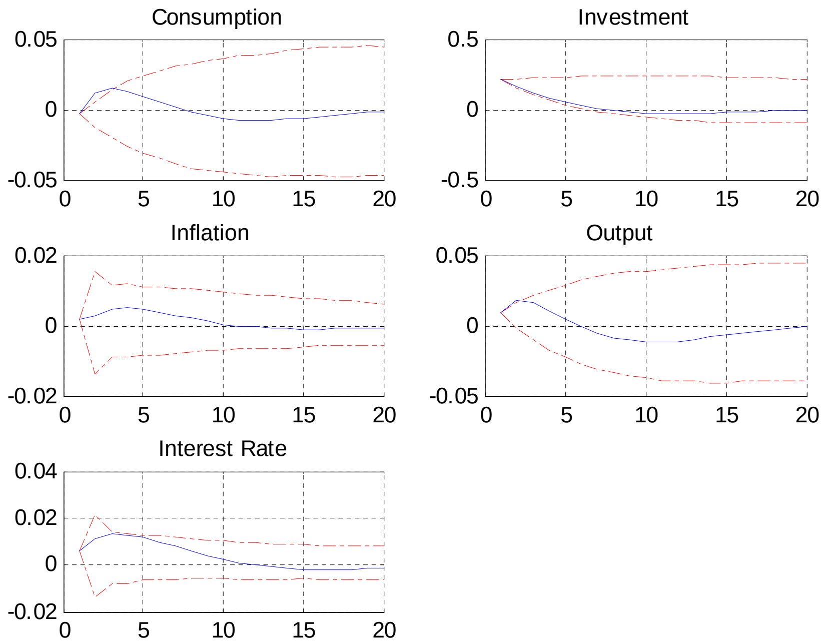

Figure 132: Investment Shock

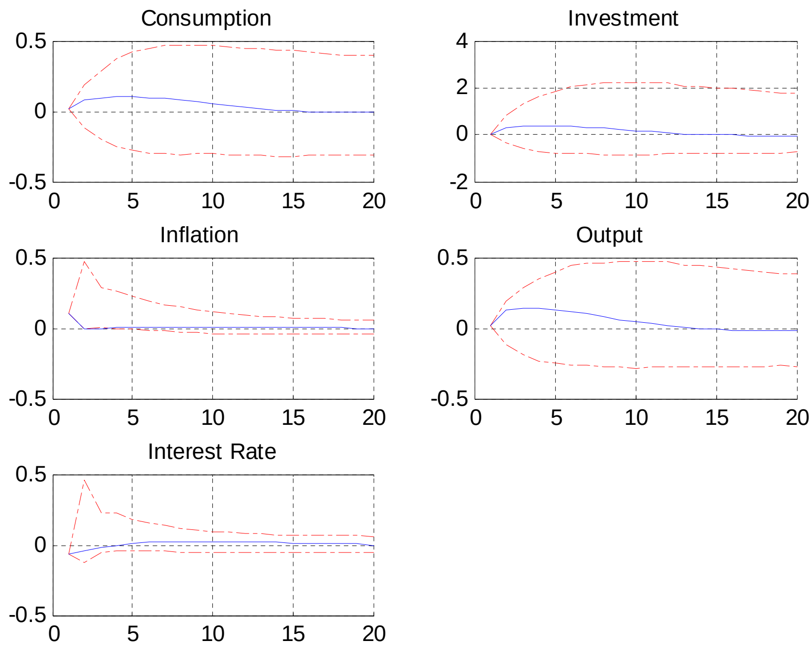

Figure 133: Price Shock

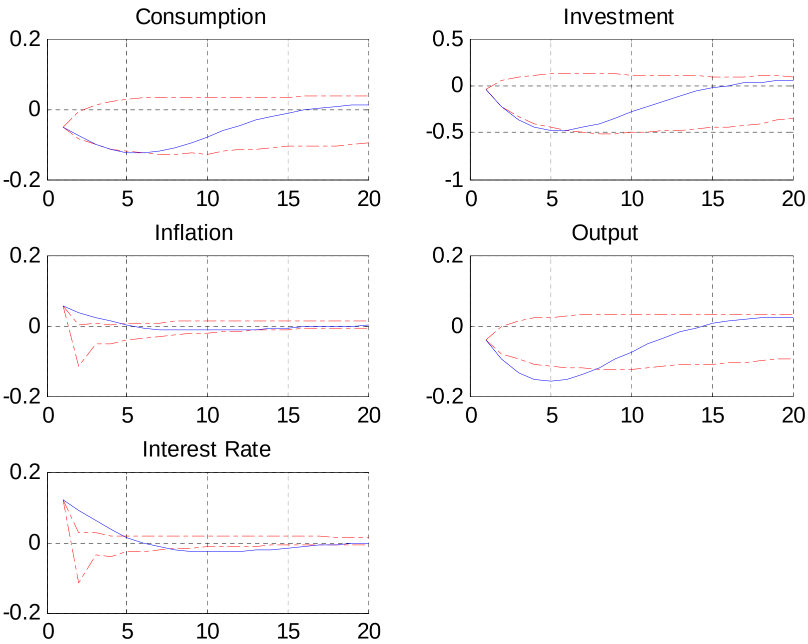

Figure 134: Wage Shock

L.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.599122	0.549034	1.157685	TRUE	-1.77957
A_C^I	0.200404	-0.861570	1.161302	TRUE	0.15603
A_C^π	-0.036330	-0.962820	-0.055040	FALSE	1.94070
A_C^Y	-0.075550	-0.153170	0.418980	TRUE	-1.45578
A_C^R	-0.034110	-1.219620	-0.117600	FALSE	2.13696
A_I^C	0.070070	-0.057840	0.042735	FALSE	2.83666
A_I^I	0.808130	0.706168	1.089690	TRUE	-1.07922
A_I^π	-0.000310	-0.088600	0.087761	TRUE	-0.11687
A_I^Y	0.070222	-0.044720	0.057433	FALSE	2.41179
A_I^R	0.031282	-0.104540	0.109092	TRUE	0.47866
A_π^C	0.341534	-0.927000	1.088636	TRUE	0.45464
A_π^I	1.368636	-2.474610	5.358801	TRUE	-0.06432
A_π^π	0.104018	-0.091650	3.127885	TRUE	-1.73913
A_π^Y	0.615056	-0.897020	1.163641	TRUE	0.82770
A_π^R	0.032078	-0.953010	2.998353	TRUE	-1.04727
A_Y^C	0.064821	-0.284250	0.475636	TRUE	-0.15264
A_Y^I	0.244816	-1.396580	1.220291	TRUE	0.42048
A_Y^π	0.088437	-0.215490	0.876909	TRUE	-0.74415
A_Y^Y	0.736872	0.390556	1.104944	TRUE	-0.15791
A_Y^R	0.010331	-0.265330	1.083179	TRUE	-1.09404
A_R^C	-0.493900	-0.854200	0.751266	TRUE	-1.06958
A_R^I	-2.136880	-4.112040	1.940417	TRUE	-0.66456
A_R^π	0.281053	-2.531980	-0.019460	FALSE	2.43378
A_R^Y	-0.850100	-0.896060	0.754857	TRUE	-1.76417
A_R^R	0.724776	-2.513030	0.544777	FALSE	2.20805
	Wald Statistic	91.9			

*t-stat from bootstrap mean

Table 55: VAR Parameters & Model Bootstrap Bounds for Flex-price Model with HP filtered data)

L.4 Results for Flex-Price Model with HP filtered data

	Prod	Cons	Gov	Inv	Price	Wage
ρ	0.616	-0.191	0.684	-0.061	0.236	0.544
Var	0.163	0.201	0.226	1.334	0.058	5.072

Table 56: AR Coefficients and Variances of Shocks for Flex-Price Model with HP filtered data

	Full varcovar	Just variances
VAR(1)	100	91.9

Table 57: Wald statistics for Flex-Price Model with HP filtered data

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	0.6722	6.3605	0.0674	0.7942	0.0722
Lower	0.0931	1.3961	0.0575	0.0920	0.0892
Upper	0.9871	12.0655	0.1138	0.8231	0.1740
Mean	0.3351	4.9006	0.0827	0.3067	0.1272

Table 58: Variance of Data and Bootstraps for Flex-Price Model with HP filtered data

	Prod	Cons	Gov	Inv	Price	Wage	TOTAL
C	19.064	9.174	5.471	14.072	0.172	52.047	100
I	2.547	0.473	0.876	91.151	0.002	4.951	100
K	3.129	0.489	1.155	89.547	0.002	5.678	100
L	25.586	5.877	19.944	6.844	0.130	41.619	100
π	3.434	79.748	0.636	0.156	1.556	14.471	100
Q	12.100	39.378	2.577	6.431	0.309	39.205	100
R	7.761	59.236	1.503	0.438	0.281	30.780	100
rk	5.681	1.824	5.863	72.967	0.032	13.633	100
W	66.567	0.647	2.078	25.864	0.011	4.832	100
Y	19.064	9.174	5.471	14.072	0.172	52.047	100

Table 59: Variance Decompositon for Flex Model with HP filtered data

L.5 Cross-Correlations for Flex-Price Model (with HP filtered data)

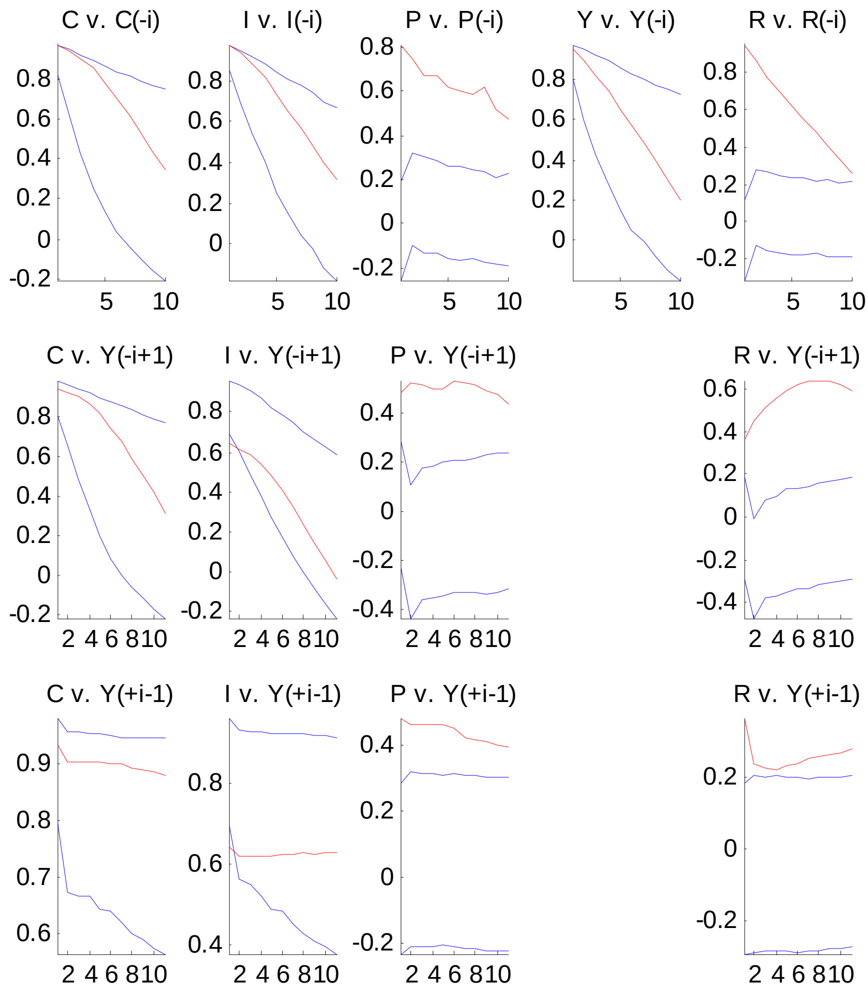

Figure 135: Cross-Correlations for Flex-Price Model (with HP filtered data)

Appendix M SW Model (re-estimated ρs) using dummied data — scaling times 0.25 for all shocks

M.1 Randomly selected Bootstraps versus Actual Data

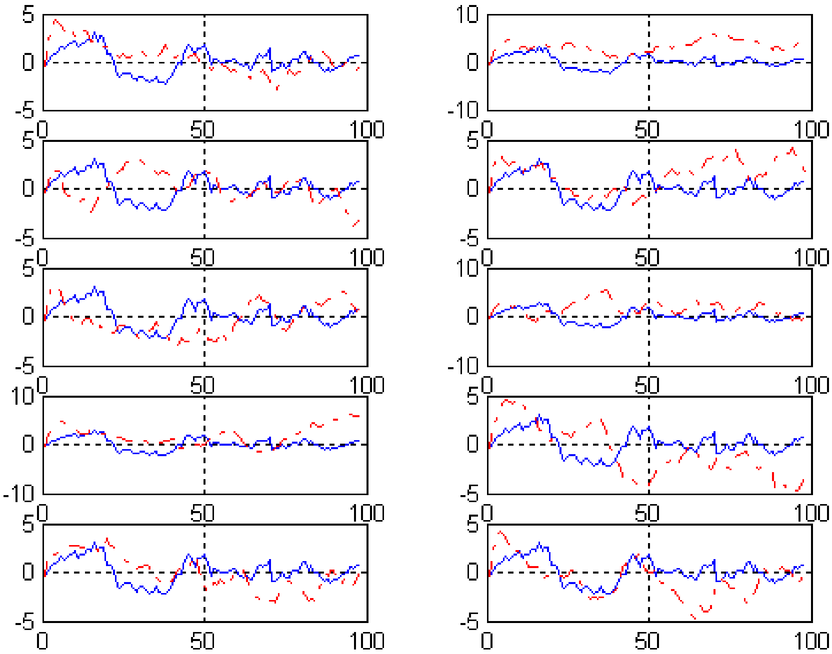

Figure 136: Consumption (Actual=blue, Simulated=red)

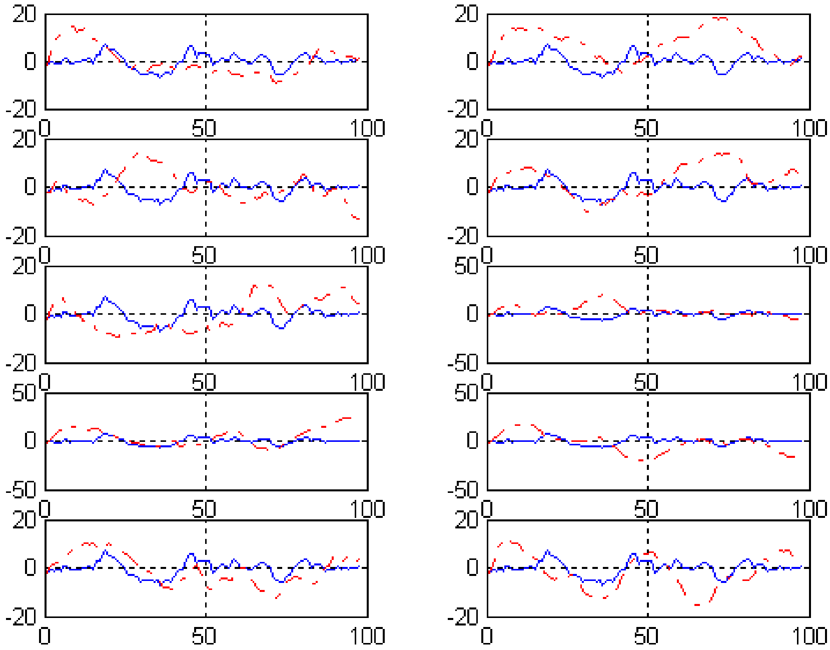

Figure 137: Investment (Actual=blue, Simulated=red)

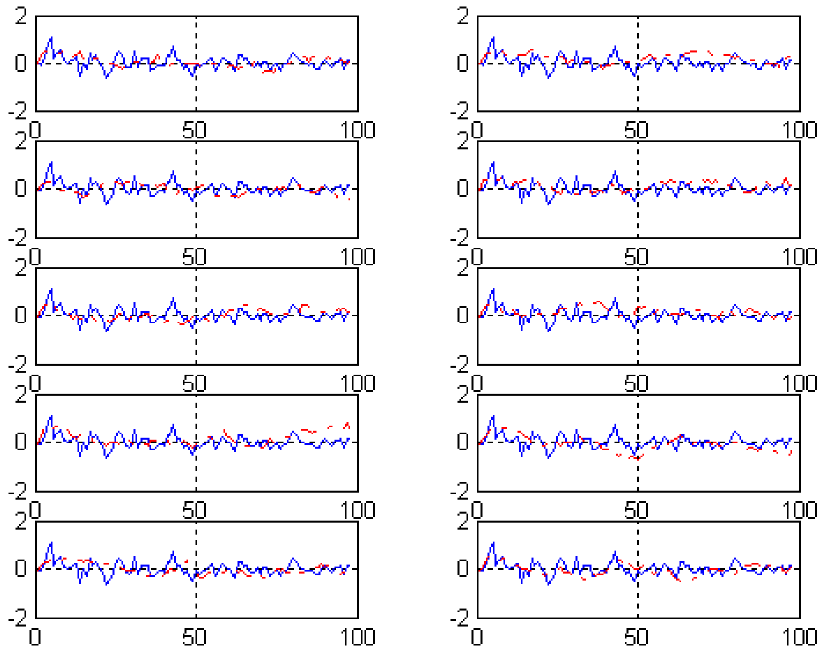

Figure 138: Inflation (Actual=blue, Simulated=red)

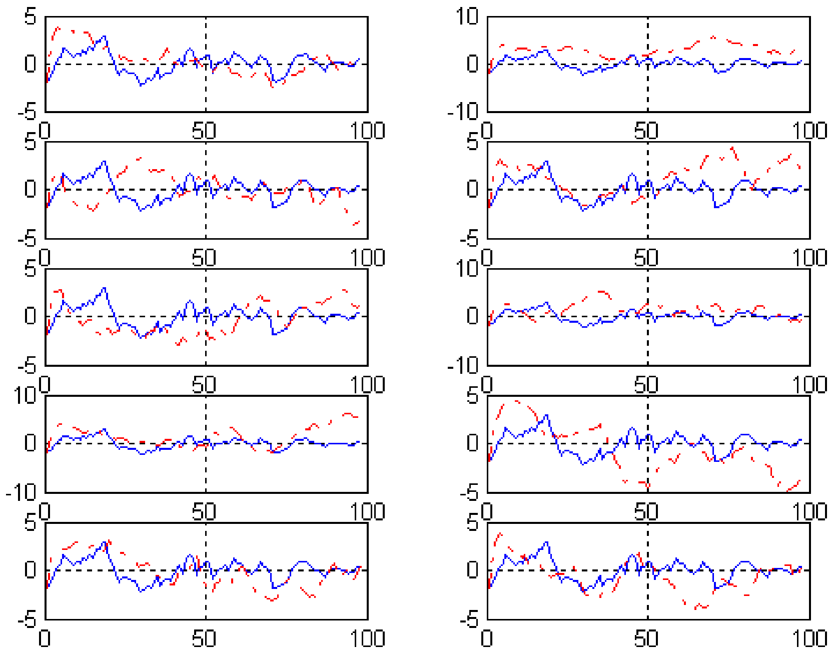

Figure 139: Output (Actual=blue, Simulated=red)

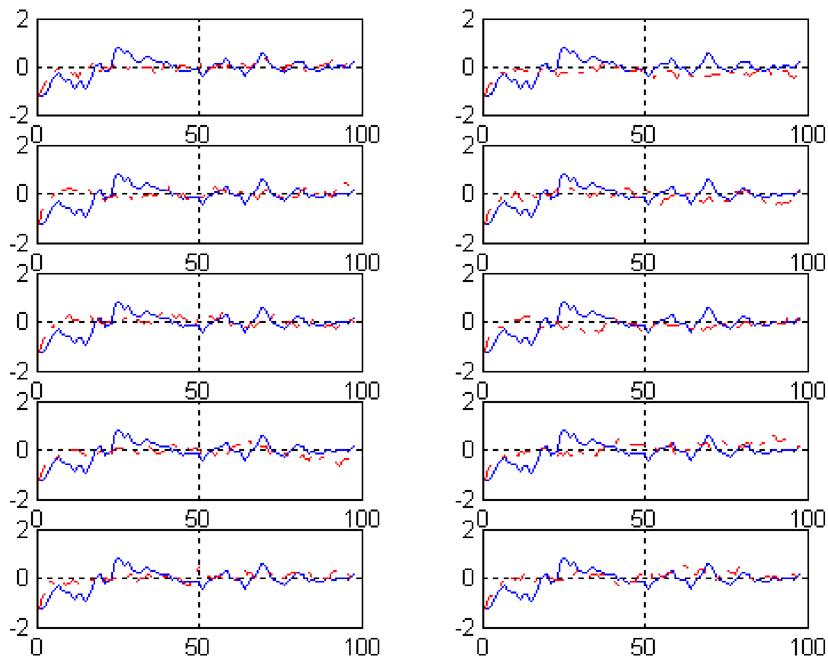

Figure 140: Interest Rate (Actual=blue, Simulated=red)

M.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

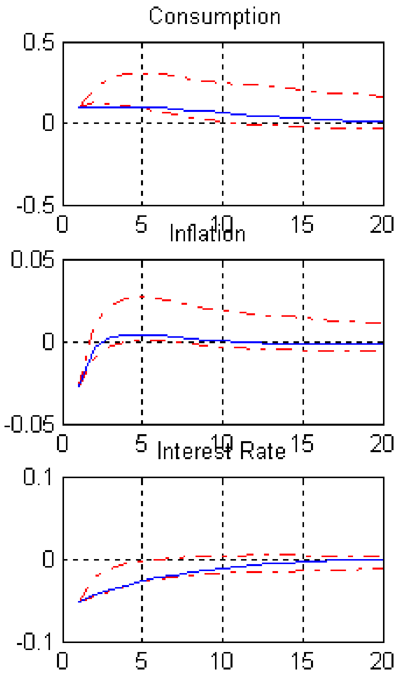

Figure 141: Productivity Shock

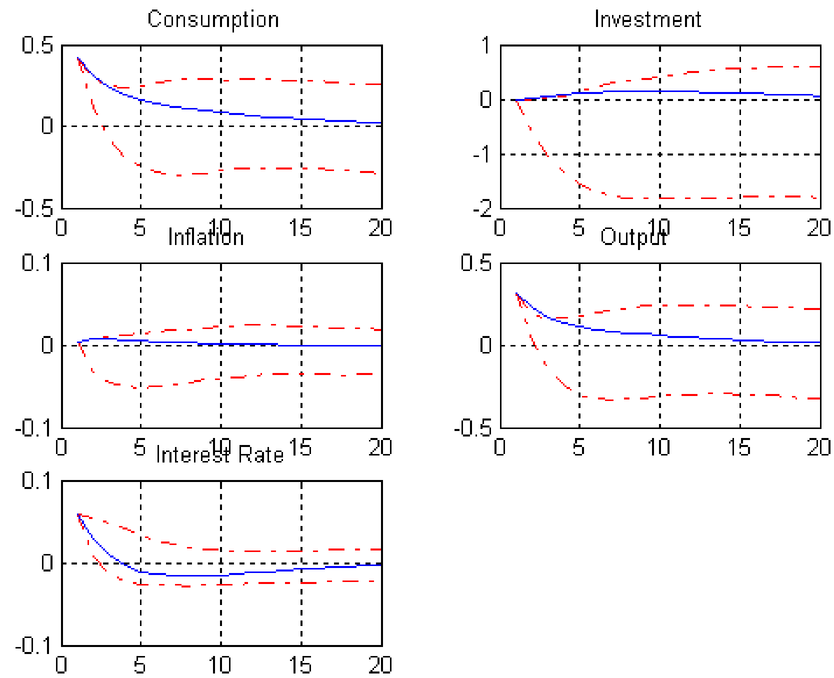

Figure 142: Preference Shock

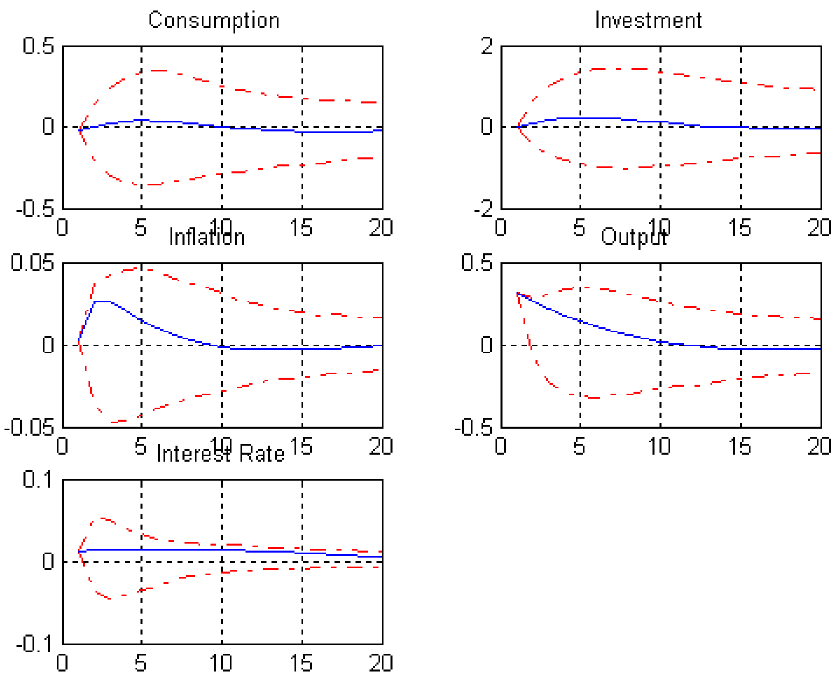

Figure 143: Government Spending Shock

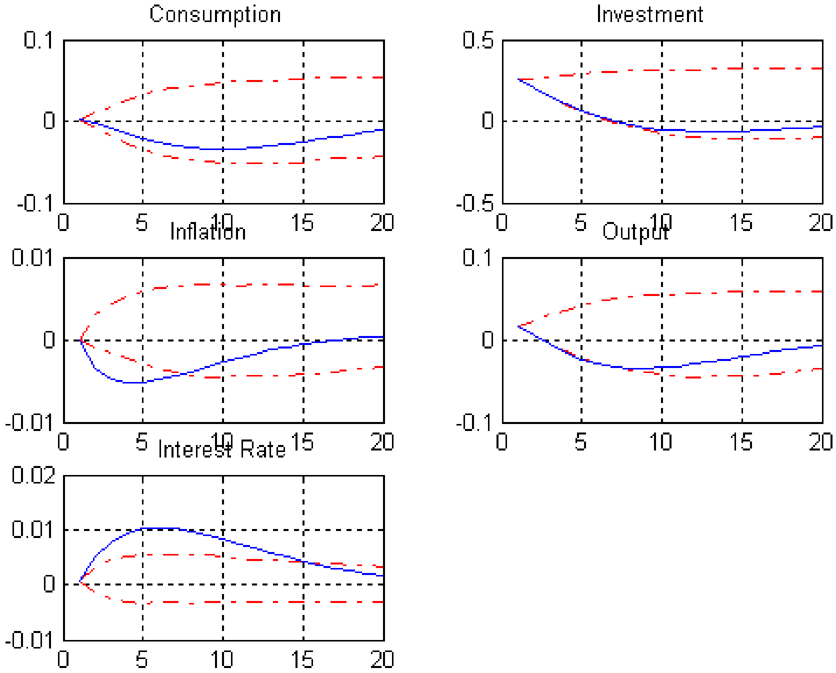

Figure 144: Investment Shock

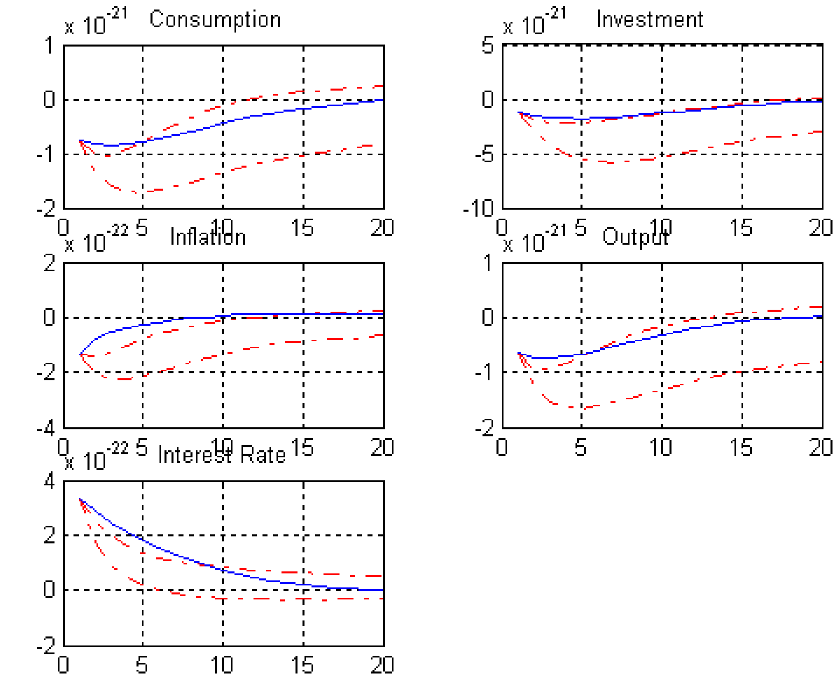

Figure 145: Price Shock

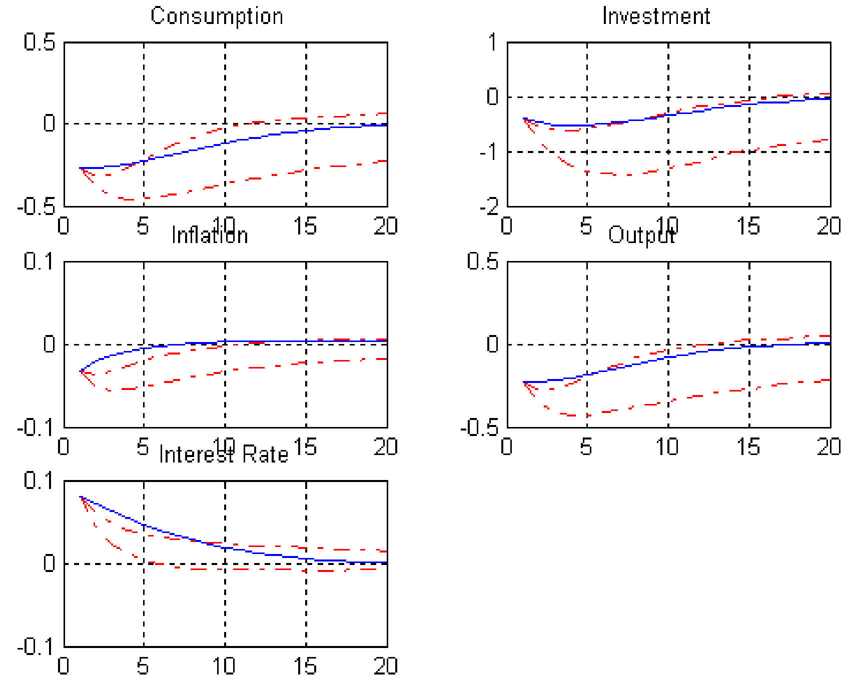

Figure 146: Monetary Shock

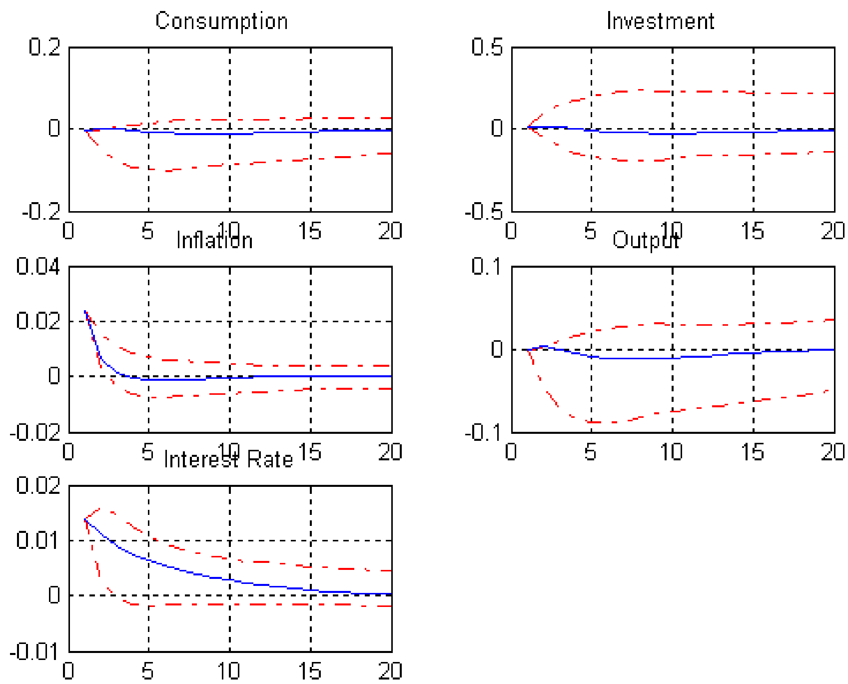

Figure 147: Wage Shock

M.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.76253	0.32698	1.23100	TRUE	0.00499
A_C^I	-0.08221	-2.08210	0.92596	TRUE	0.75766
A_C^π	-0.03438	-0.10895	0.09995	TRUE	-0.57264
A_C^Y	-0.01727	-0.22468	0.70674	TRUE	-1.03280
A_C^R	-0.05315	-0.13717	0.10730	TRUE	-0.63704
A_I^C	-0.01398	-0.03567	0.04638	TRUE	-0.95154
A_I^I	0.77631	0.74775	1.01530	TRUE	-1.60760
A_I^π	-0.01749	-0.00401	0.01264	FALSE	-4.95500
A_I^Y	-0.02802	-0.00265	0.08113	FALSE	-3.09750
A_I^R	0.01668	-0.00919	0.01466	FALSE	2.43100
A_π^C	0.49287	-0.86573	0.98826	TRUE	0.99144
A_π^I	0.82397	-0.48868	5.70230	TRUE	-1.21480
A_π^π	0.34213	0.30237	0.78267	TRUE	-1.92110
A_π^Y	0.48765	-0.71567	1.11060	TRUE	0.71224
A_π^R	-0.01645	-0.20073	0.26735	TRUE	-0.39981
A_Y^C	0.07046	-0.52707	0.49363	TRUE	0.22479
A_Y^I	0.36224	-1.27410	2.08360	TRUE	-0.13876
A_Y^π	0.07926	-0.10523	0.12024	TRUE	1.25710
A_Y^Y	0.82759	-0.14377	0.89556	TRUE	1.55420
A_Y^R	0.00923	-0.14012	0.14012	TRUE	0.17983
A_R^C	-0.51815	-2.35840	-1.27000	FALSE	4.95900
A_R^I	-0.91067	-5.43020	-2.00230	FALSE	3.25110
A_R^π	-0.07914	-0.39795	-0.16597	FALSE	3.45760
A_R^Y	-0.55768	-2.38410	-1.35590	FALSE	5.03120
A_R^R	0.81349	0.49127	0.77571	FALSE	2.41800
	Wald Statistic	99.8			

*t-stat from bootstrap mean

Table 60: VAR Parameters & Model Bootstrap Bounds (SW with Dummied Data)

M.4 Results for SW Model with dummied data

	Prod	Cons	Gov	Inv	Price	Int	Wage
ρ	0.781	-0.037	0.718	0.137	-0.148	0.109	0.049
Var	0.318	0.260	0.294	1.890	0.061	0.539	0.336

Table 61: AR Coefficients and Variances of Shocks for SW Model with estimated rhos and Dummied data

	Full varcovar	Just variances
VAR(1)	100	99.8
VAR(2)	100	99.3
VAR(3)	100	65.8

Table 62: Wald statistics for SW Model with estimated rhos and Dummied data

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	1.5476	8.9366	0.0752	1.1663	0.1536
Lower	0.9935	13.6734	0.0217	0.9810	0.0340
Upper	5.6388	101.5204	0.0805	5.5332	0.0700
Mean	2.6169	44.5696	0.0452	2.5837	0.0491

Table 63: Variance of Data and Bootstraps for SW Model with estimated rhos and Dummied data

	Prod	Cons	Gov	Inv	Price	Int	Wage	TOTAL
c	0.496	1.456	0.033	0.698	0.253	96.788	0.277	100
I	0.353	0.002	0.015	7.094	0.282	92.030	0.224	100
K	0.425	0.002	0.019	4.824	0.272	94.166	0.291	100
L	4.100	1.342	1.750	0.719	0.220	91.479	0.390	100
π	0.381	0.024	0.016	0.122	12.555	84.792	2.111	100
Q	0.205	0.043	0.011	0.818	0.277	98.502	0.143	100
R	2.351	2.513	0.302	0.432	0.777	92.865	0.761	100
rk	1.062	0.416	0.467	3.050	0.548	91.608	2.848	100
w	0.205	0.029	0.009	0.732	0.861	89.214	8.950	100
Y	0.468	0.964	1.242	0.947	0.259	95.854	0.266	100

Table 64: Variance Decompositon for SW Model with estimated rhos and Dummied data

M.5 Cross-Correlations for SW's Model with estimated ρs (with dummied data)

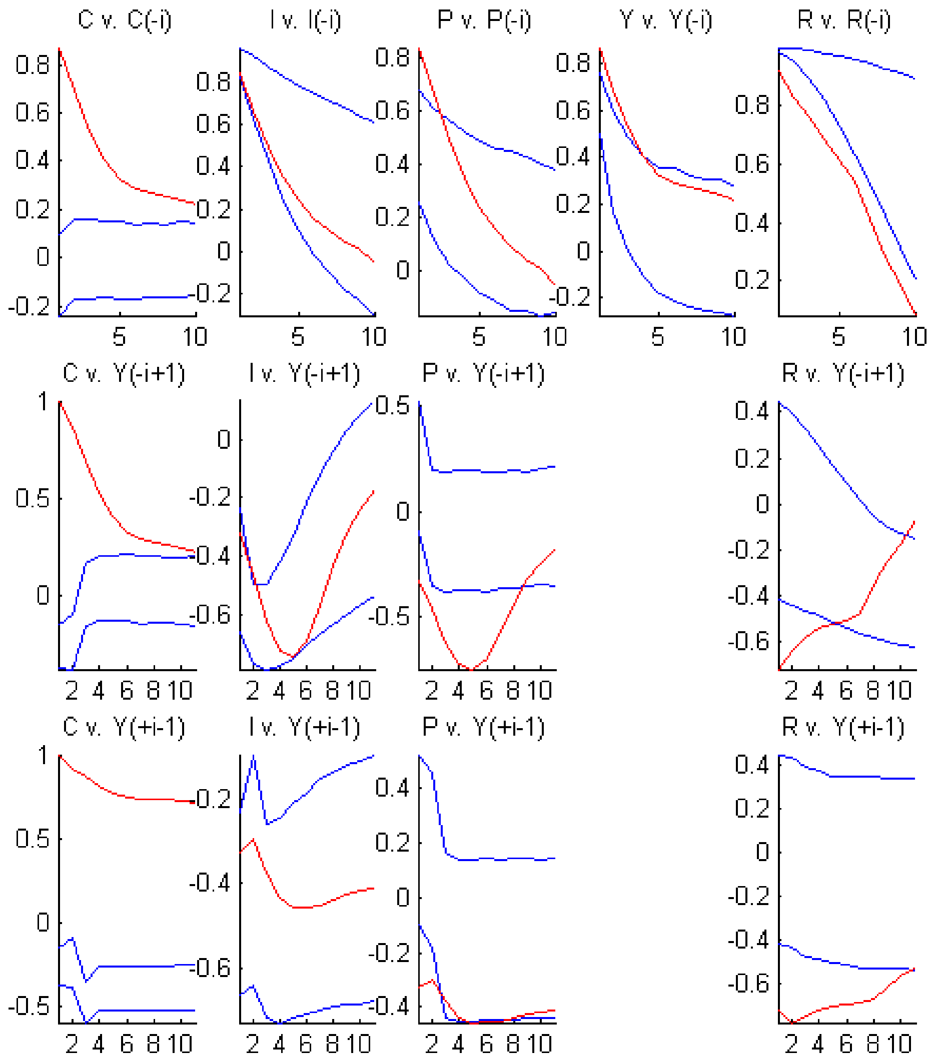

Figure 148: Cross-Correlations for SW's Model with estimated ρs (with dummied data)

Appendix N Flexprice Version of SW's Model with Dummied Data — scaling times 0.77 for all shocks

N.1 Randomly selected Bootstraps versus Actual Data

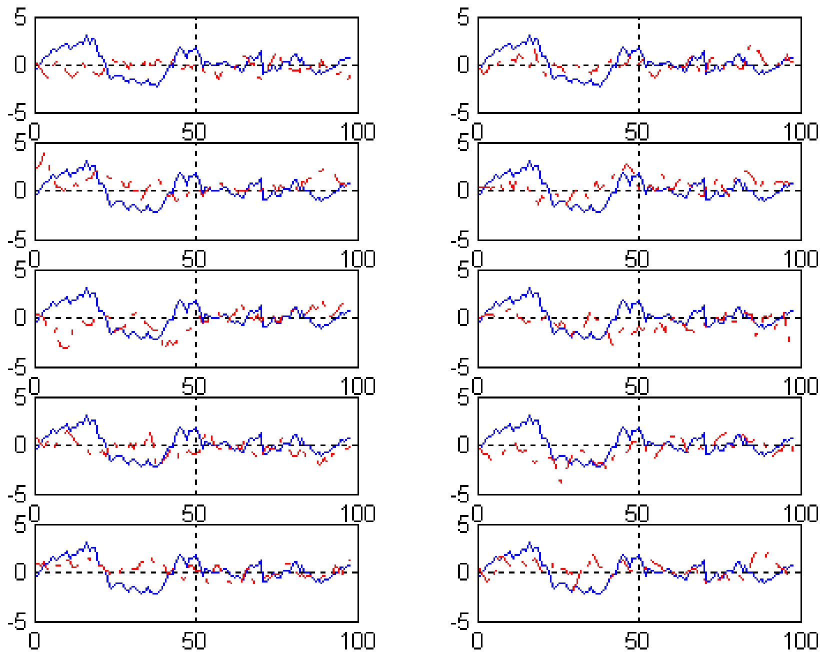

Figure 149: Consumption (Actual=blue, Simulated=red)

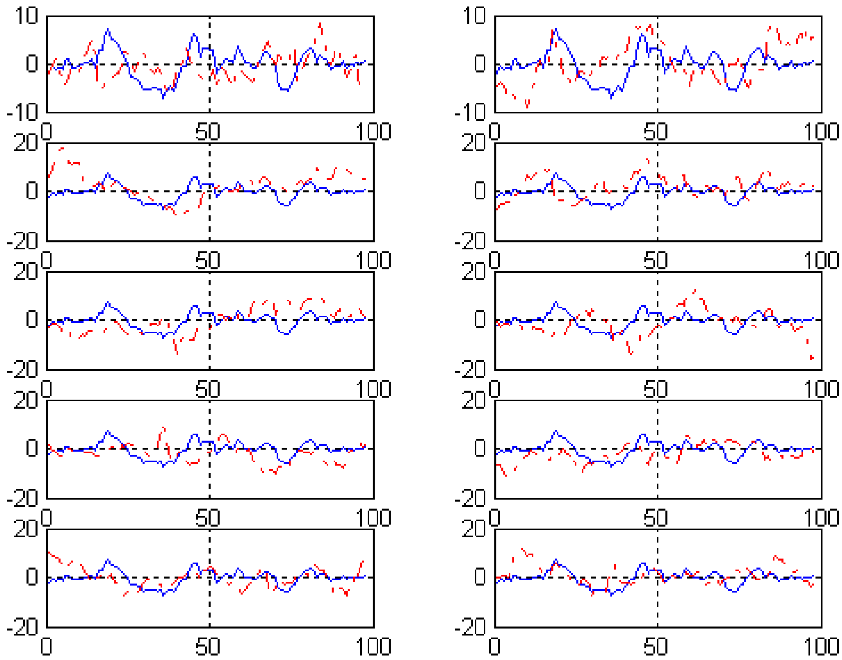

Figure 150: Investment (Actual=blue, Simulated=red)

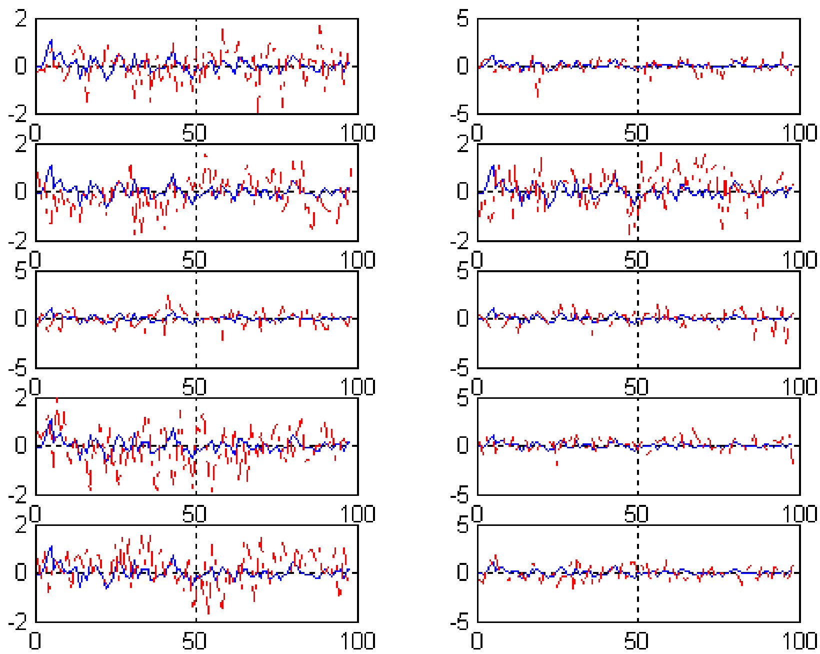

Figure 151: Inflation (Actual=blue, Simulated=red)

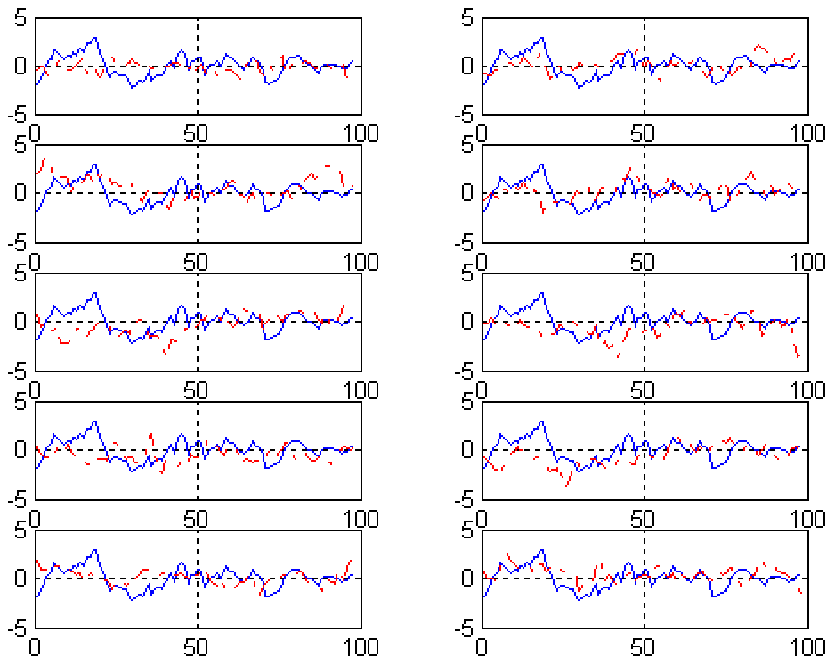

Figure 152: Output (Actual=blue, Simulated=red)

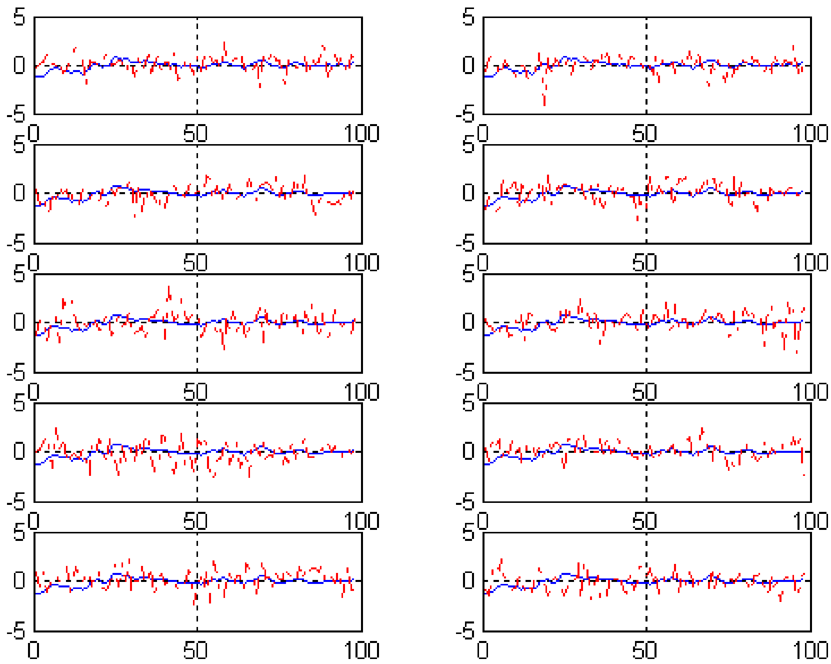

Figure 153: Interest Rate (Actual=blue, Simulated=red)

N.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

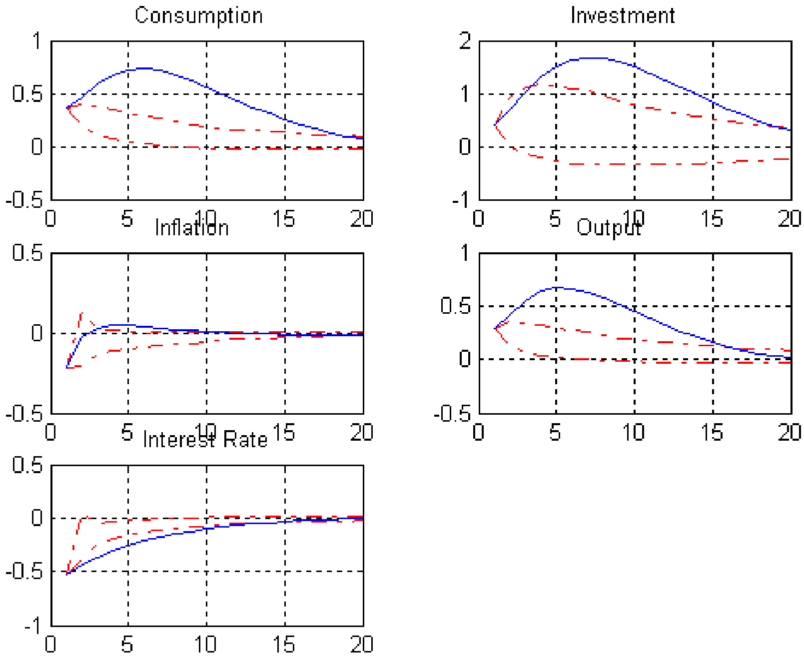

Figure 154: Productivity Shock

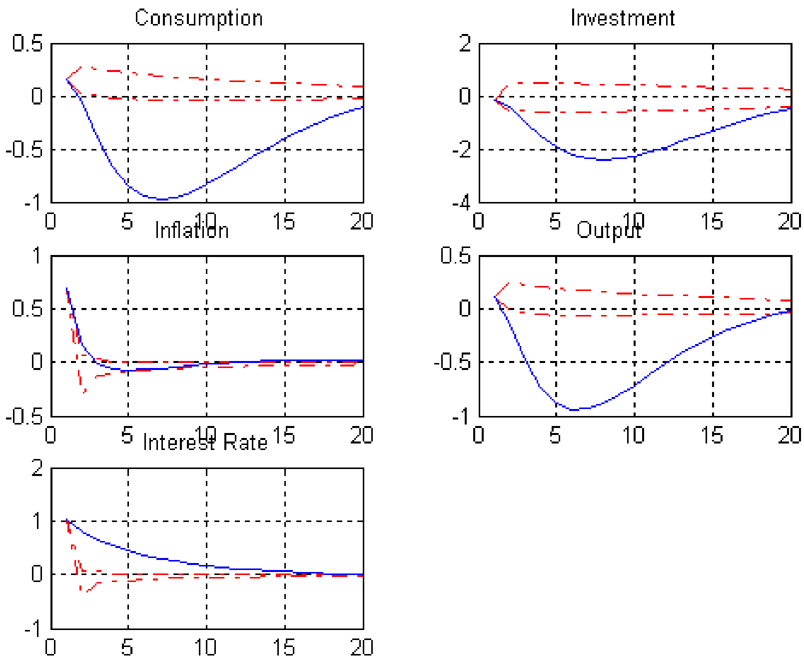

Figure 155: Preference Shock

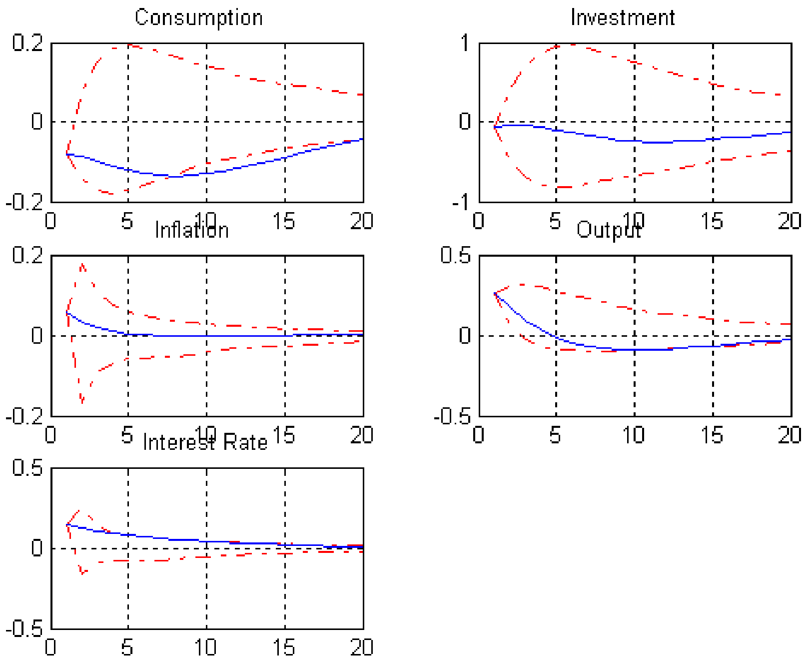

Figure 156: Government Spending Shock

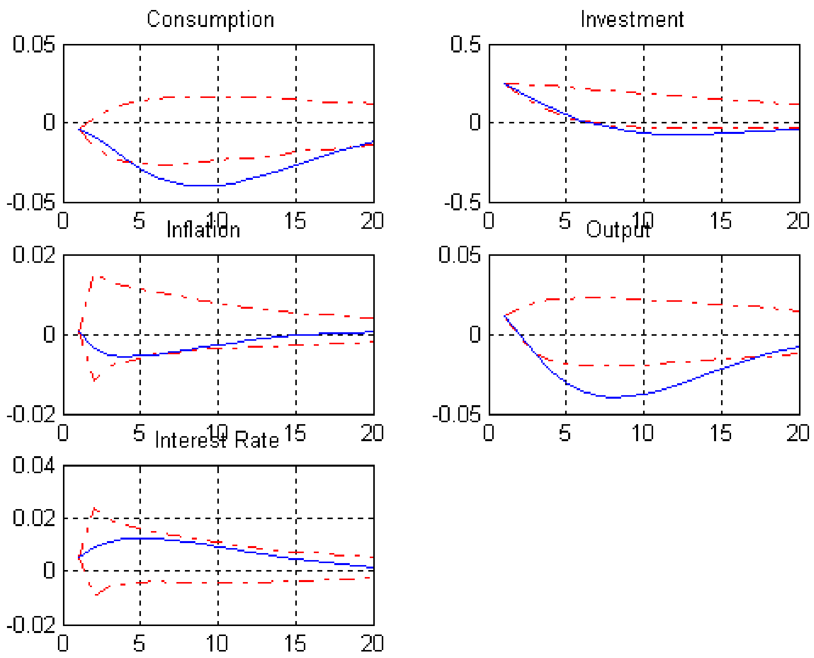

Figure 157: Investment Shock

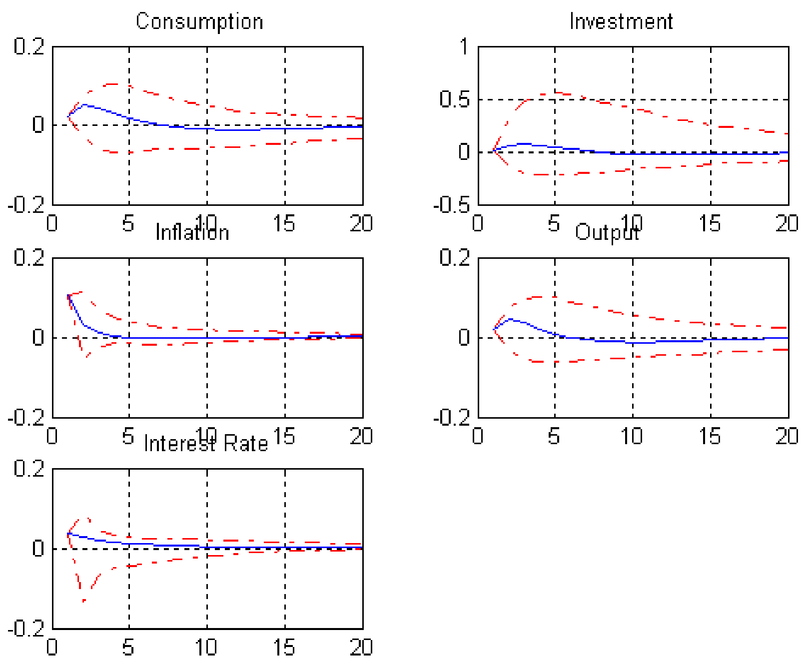

Figure 158: Price Shock

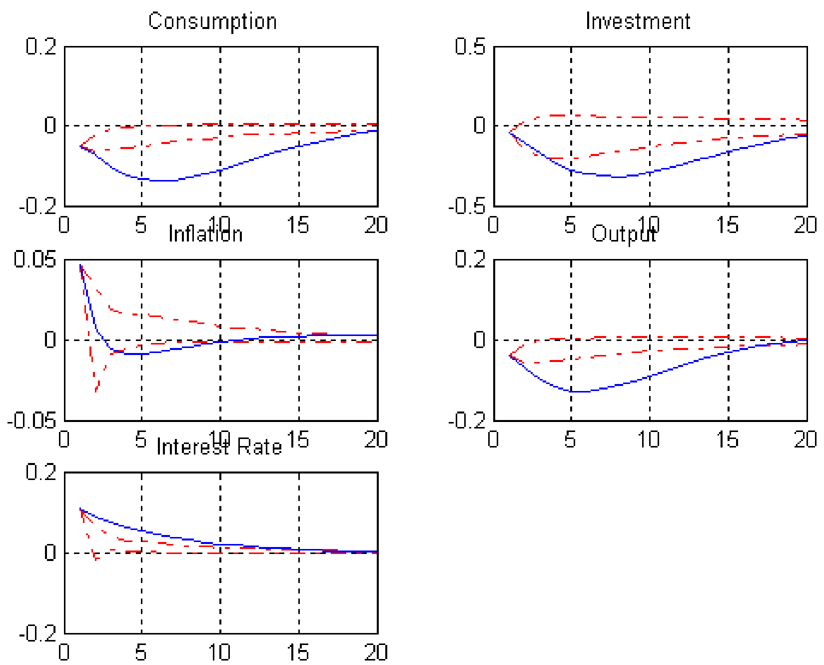

Figure 159: Wage Shock

N.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.76253	0.45454	1.07140	TRUE	-0.12737
A_C^I	-0.08221	-1.39840	1.11320	TRUE	0.08364
A_C^π	-0.03438	-0.88711	0.13948	TRUE	1.27920
A_C^Y	-0.01727	-0.23543	0.38592	TRUE	-0.60874
A_C^R	-0.05315	-1.14750	0.12488	TRUE	1.36010
A_I^C	-0.01398	-0.05653	0.03079	TRUE	-0.13900
A_I^I	0.77631	0.66031	1.03110	TRUE	-0.89199
A_I^π	-0.01749	-0.06880	0.08168	TRUE	-0.73155
A_I^Y	-0.02802	-0.04435	0.04735	TRUE	-1.32390
A_I^R	0.01668	-0.07432	0.10659	TRUE	-0.02794
A_π^C	0.49287	-0.67482	0.80170	TRUE	1.25840
A_π^I	0.82397	-2.09530	3.92280	TRUE	-0.05354
A_π^π	0.34213	-0.70348	1.63060	TRUE	-0.25188
A_π^Y	0.48765	-0.64235	0.80417	TRUE	1.16090
A_π^R	-0.01645	-1.62320	1.28950	TRUE	0.20772
A_Y^C	0.07046	-0.27024	0.46773	TRUE	-0.05234
A_Y^I	0.36224	-1.17590	1.65150	TRUE	0.19265
A_Y^π	0.07926	-0.51901	0.56585	TRUE	0.23569
A_Y^Y	0.82759	0.35844	1.07500	TRUE	0.46197
A_Y^R	0.00923	-0.64175	0.69499	TRUE	0.01653
A_R^C	-0.51815	-0.59026	0.51401	TRUE	-1.83220
A_R^I	-0.91067	-2.89990	1.73910	TRUE	-0.32251
A_R^π	-0.07914	-1.24150	0.51001	TRUE	0.69133
A_R^Y	-0.55768	-0.60186	0.49686	TRUE	-1.91670
A_R^R	0.81349	-1.05170	1.12010	TRUE	1.35250
	Wald Statistic	49.1			

*t-stat from bootstrap mean

Table 65: VAR Parameters & Model Bootstrap Bounds for Flex-price Model with Dummied data)

N.4 Results for Flex-Price Model with dummied data

	Prod	Cons	Gov	Inv	Price	Wage
ρ	0.781	-0.037	0.718	0.137	0.742	0.627
Var	0.318	0.260	0.294	1.890	0.185	6.975

Table 66: AR Coefficients and Variances of Shocks for Flex-Price Model with Dummied data

	Full varcovar	Just variances
VAR(1)	100	49.1
VAR(2)	100	90.9
VAR(3)	100	58.0

Table 67: Wald statistics for Flex-Price Model with Dummied data

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	1.5476	8.9366	0.0752	1.1663	0.1536
Lower	0.4395	10.5406	0.4386	0.4443	0.7535
Upper	1.7400	54.7603	0.8655	1.9088	1.4554
Mean	0.9200	26.7864	0.6290	0.9711	1.0720

Table 68: Variance of Data and Bootstraps for Flex-Price Model with Dummied data

	Prod	Cons	Gov	Inv	Price	Wage	TOTAL
c	38.279	3.706	4.534	12.463	0.066	40.952	100
I	11.443	0.543	0.880	81.041	0.001	6.092	100
K	15.748	0.513	1.091	75.832	0.001	6.816	100
L	33.648	2.626	17.840	6.834	0.059	38.994	100
π	4.860	71.167	1.013	0.297	5.744	16.920	100
Q	19.593	31.927	2.746	8.476	0.174	37.084	100
R	9.222	57.788	1.865	0.643	1.020	29.461	100
rk	17.341	0.975	4.705	64.512	0.012	12.455	100
w	77.230	0.269	1.296	17.771	0.003	3.431	100
$E_{t-1}\pi_t$	18.033	0.410	3.449	1.867	27.808	48.434	100
Y	35.334	2.219	14.743	12.736	0.049	34.919	100

Table 69: Variance Decompositon for Flex Model with Dummied data

N.5 Cross-Correlations for Flex-Price Model (with dummied data)

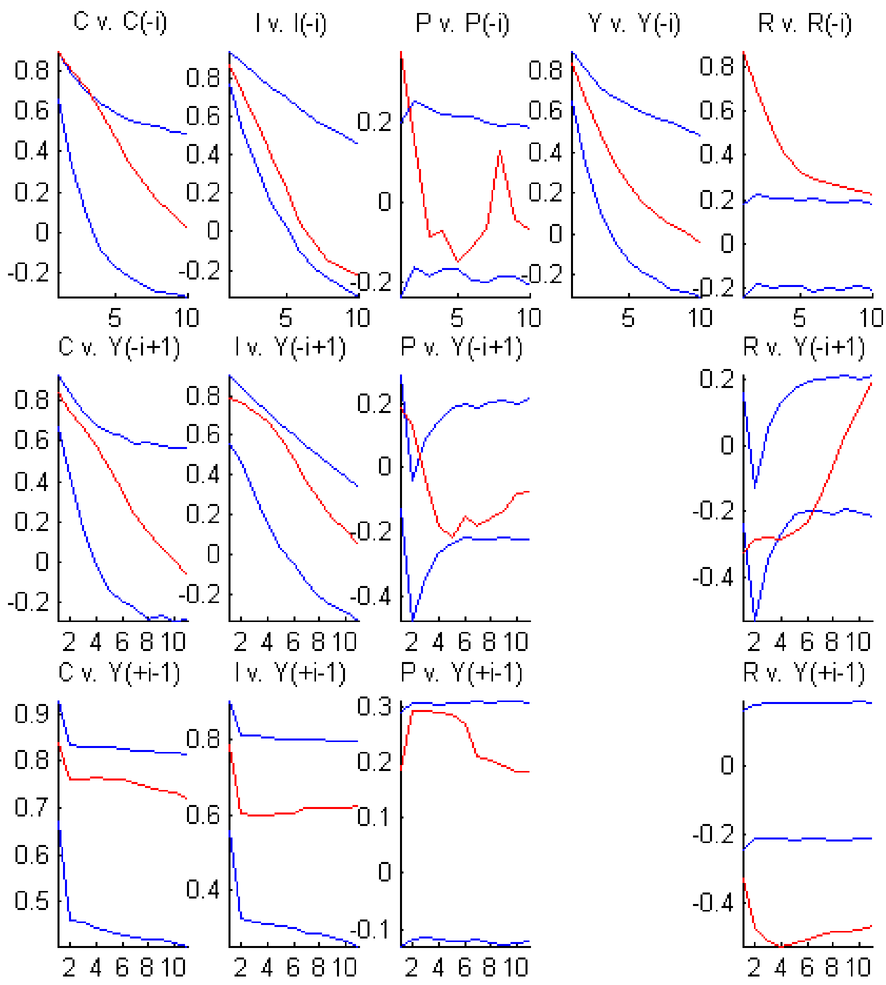

Figure 160: Cross-Correlations for Flex-Price Model (with dummied data)

Appendix O Weighted Version of the Model — no scaling for all shocks

O.1 Randomly selected Bootstraps versus Actual Data

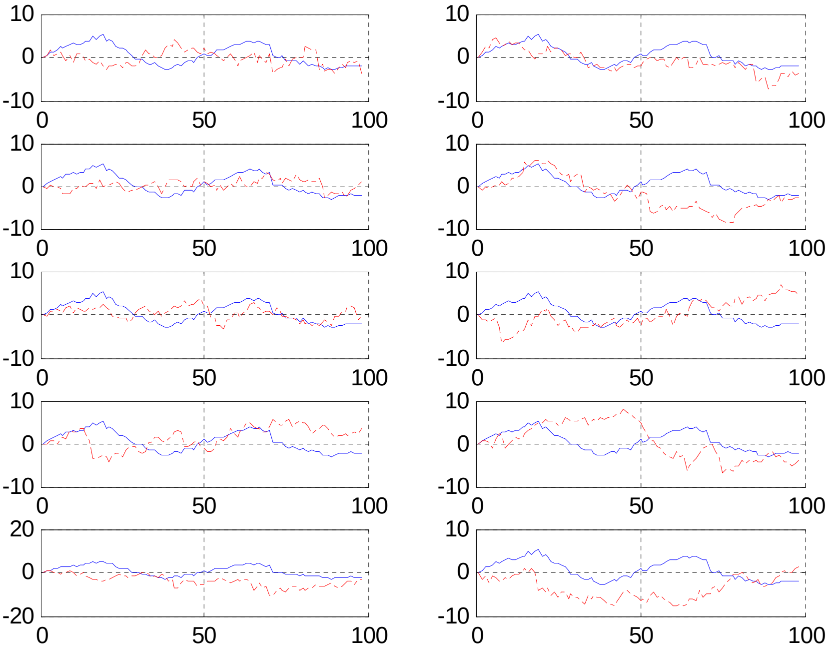

Figure 161: Consumption (Actual=blue, Simulated=red)

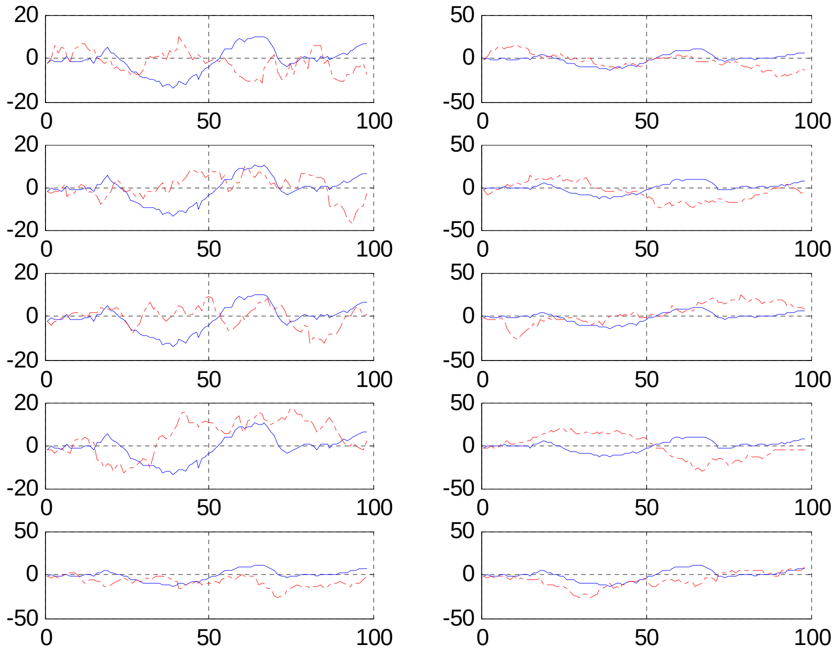

Figure 162: Investment (Actual=blue, Simulated=red)

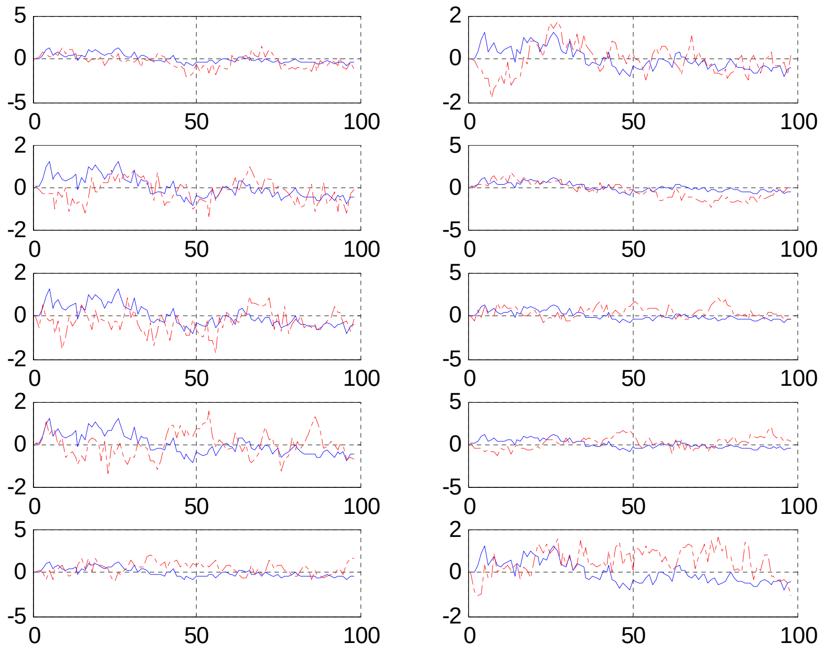

Figure 163: Inflation (Actual=blue, Simulated=red)

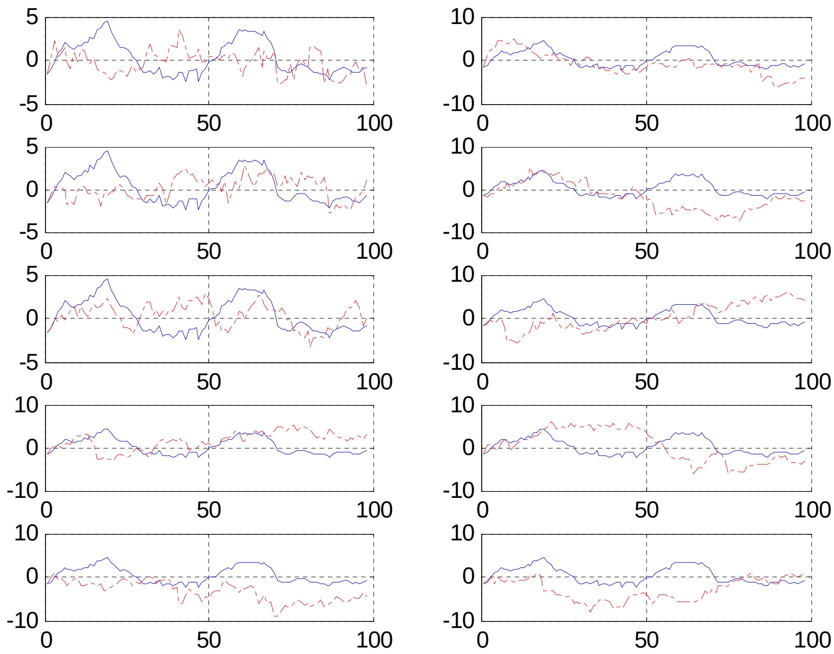

Figure 164: Output (Actual=blue, Simulated=red)

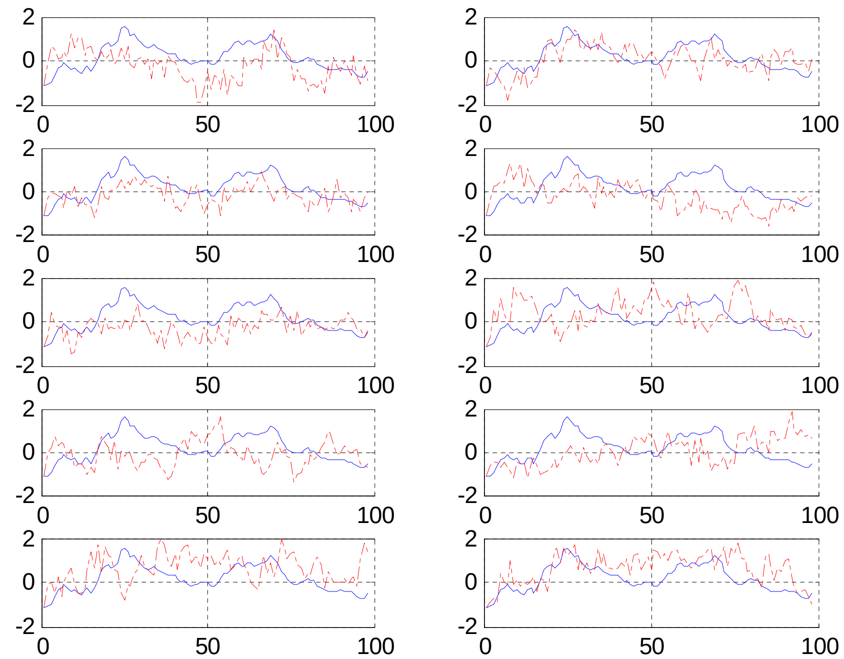

Figure 165: Interest Rate (Actual=blue, Simulated=red)

O.2 Analysis of IRFs of VAR (blue) versus 95% VAR bounds implied by the model

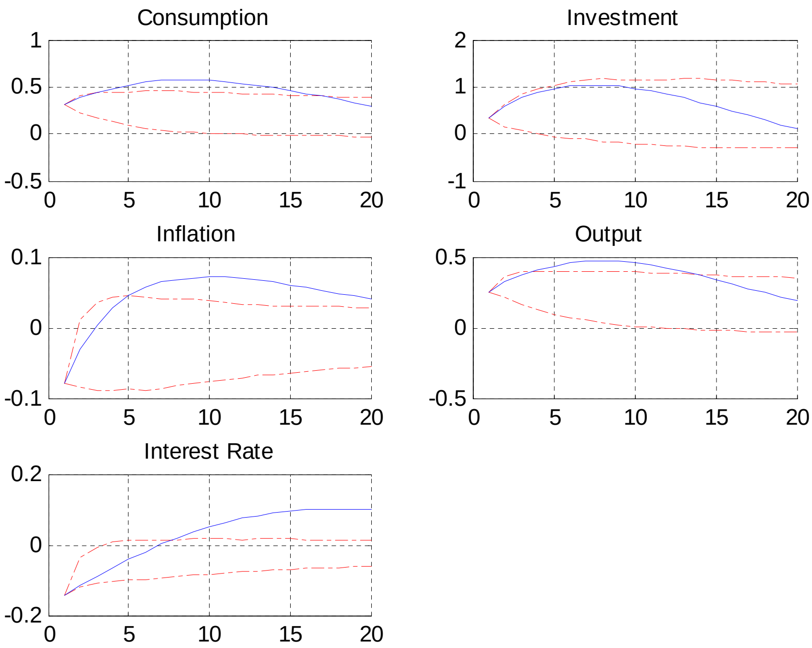

Figure 166: Productivity Shock

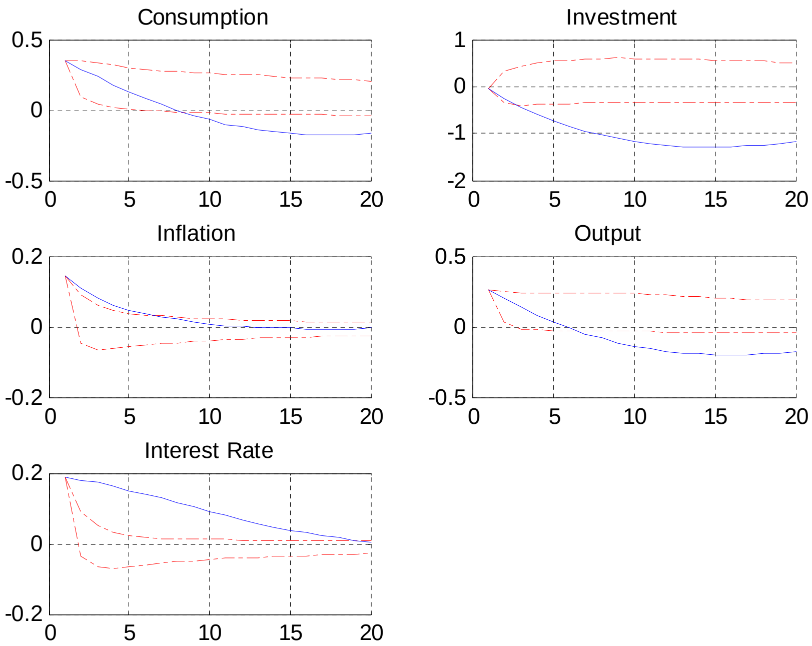

Figure 167: Consumer Preference Shock

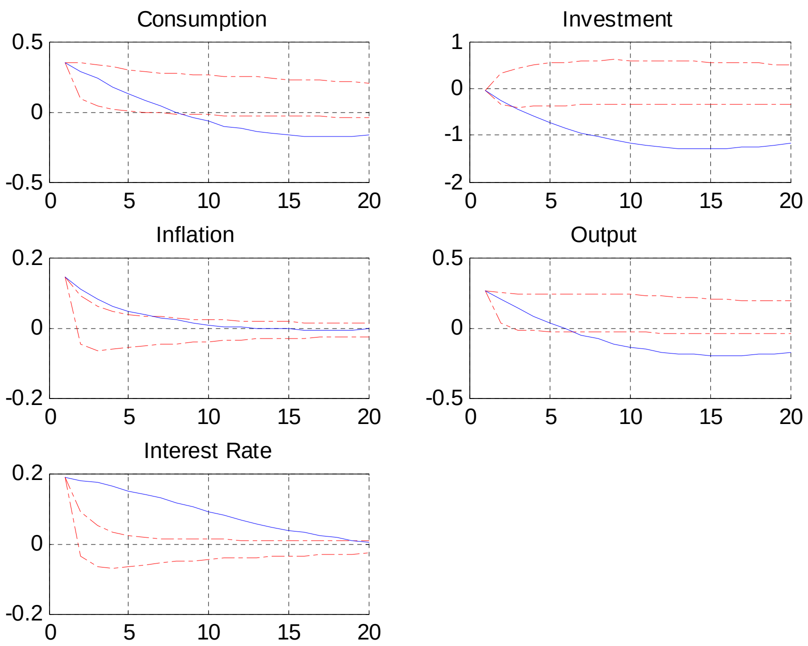

Figure 168: Government Spending Shock

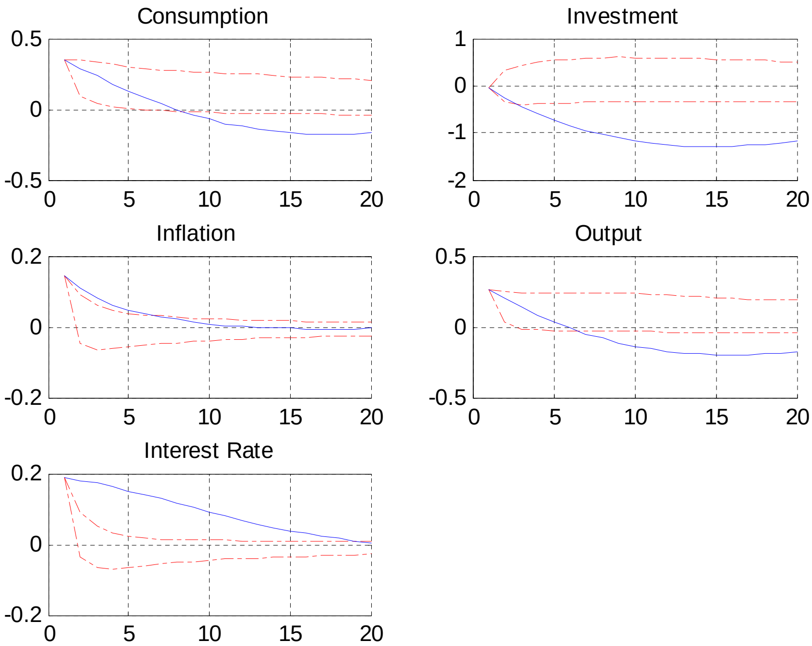

Figure 169: Investment Shock

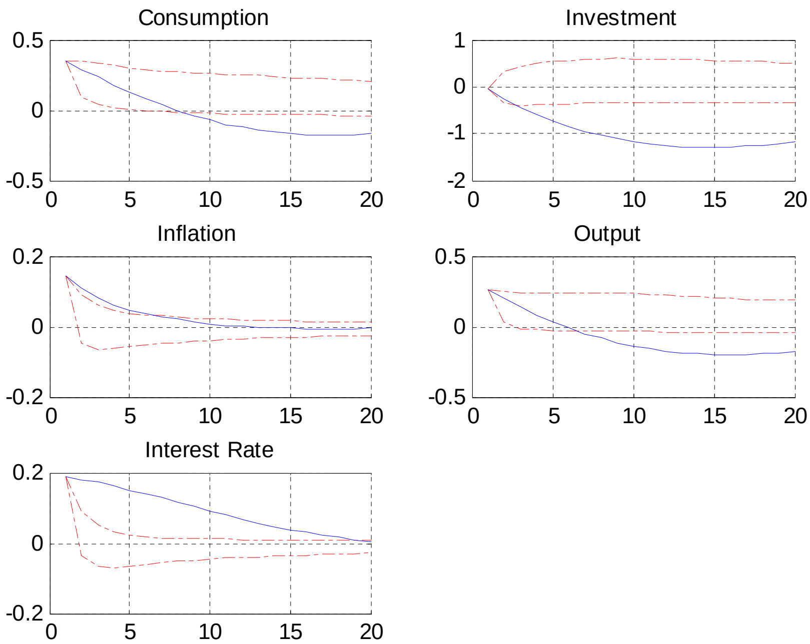

Figure 170: Price Shock

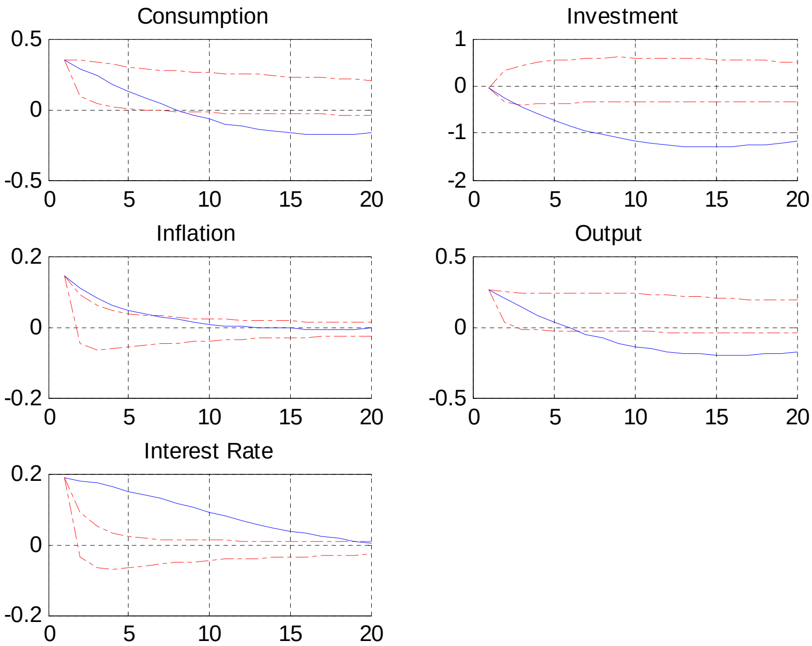

Figure 171: Wage Shock (NC)

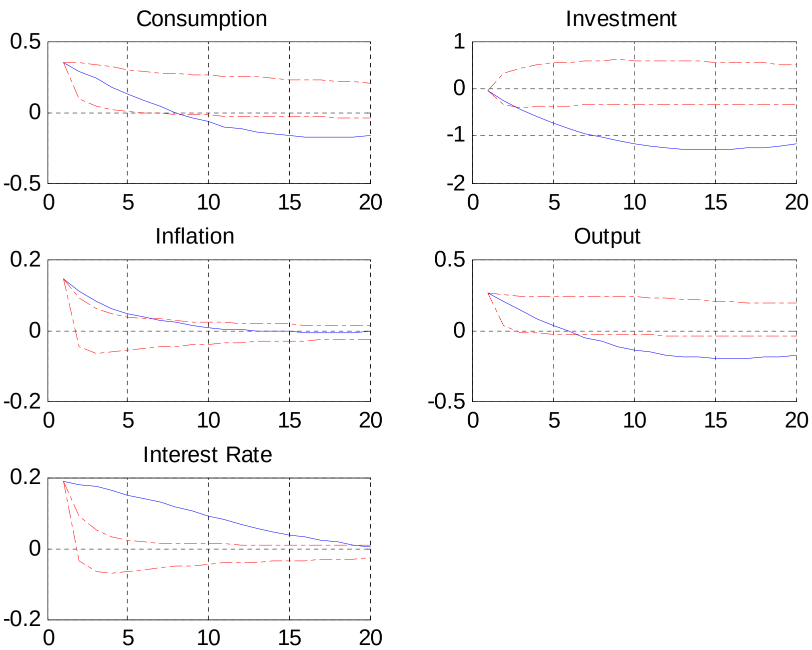

Figure 172: Wage Shock (SW)

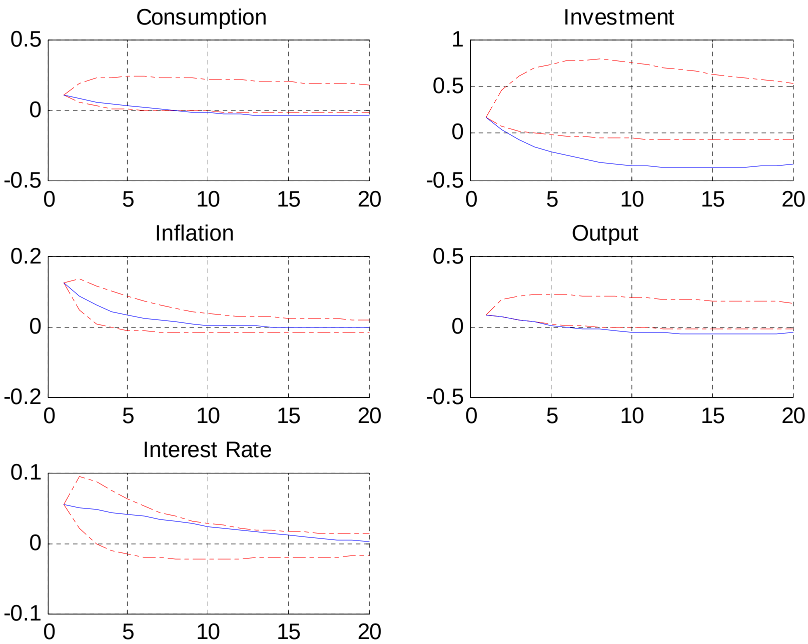

Figure 173: Taylor Rule Shock

O.3 VAR Parameters, Model Bootstrap Bounds and Wald statistic

	Actual Estimate	Lower Bound	Upper Bound	State	t-stat*
A_C^C	0.88432	0.26572	1.02827	TRUE	1.17662
A_C^I	-0.09612	-0.92015	1.19403	TRUE	-0.39647
A_C^π	0.01867	-0.30244	0.08489	TRUE	1.27573
A_C^Y	0.07935	-0.36553	0.28805	TRUE	0.72452
A_C^R	-0.00824	-0.33625	-0.00284	TRUE	1.83460
A_I^C	-0.02461	-0.06640	0.06491	TRUE	-0.75793
A_I^I	0.91856	0.68054	1.05976	TRUE	0.30909
A_I^π	-0.01074	-0.02810	0.05323	TRUE	-1.14494
A_I^Y	-0.01190	-0.04254	0.07168	TRUE	-0.91032
A_I^R	-0.00504	-0.01937	0.04928	TRUE	-1.13906
A_π^C	-0.04105	-0.28473	1.84441	TRUE	-1.51365
A_π^I	-0.71538	-1.68976	4.13846	TRUE	-1.38882
A_π^π	0.68194	0.44617	1.57336	TRUE	-1.23414
A_π^Y	-0.00692	0.08981	1.93824	FALSE	-2.00415
A_π^R	-0.01605	0.10374	1.04049	FALSE	-2.51828
A_Y^C	0.21989	-0.27066	0.71764	TRUE	0.03638
A_Y^I	0.38855	-1.34895	1.33299	TRUE	0.50045
A_Y^π	0.05457	-0.25489	0.27741	TRUE	0.25731
A_Y^Y	0.93795	0.38837	1.25734	TRUE	0.42118
A_Y^R	0.06281	-0.19508	0.25990	TRUE	0.19567
A_R^C	-0.37666	-2.04721	0.26606	TRUE	0.87186
A_R^I	-0.97612	-4.17678	2.09513	TRUE	0.07900
A_R^π	-0.05704	-1.05222	0.07775	TRUE	1.45411
A_R^Y	-0.40669	-2.12602	-0.15480	TRUE	1.28935
A_R^R	0.89695	-0.52286	0.45459	FALSE	3.79338
	Wald Statistic	90.8			

*t-stat from bootstrap mean

Table 70: VAR Parameters & Model Bootstrap Bounds for Weighted Model

O.4 Results for Weighted Model

Prod	Cons	Gov	Inv	Lab	Price	Equity	Int	Wage SW	Wage NC	Taylor Rule
0.94	-0.101	0.751	0.063	0.994	-0.154	0.938	0.565	-0.038	0.905	0.901

Table 71: AR Coefficients and Variances of Shocks for Weighted Model

	Full varcovar	Just variances	Direct vars/Actual covars
VAR(1)	100	90.8	94.1

Table 72: Wald statistics for Weighted Model

	Consumption	Investment	Inflation	Output	Interest Rate
Actual	5.4711	37.1362	0.2459	3.6085	0.3636
Lower	1.7200	20.7905	0.2292	1.5284	0.2036
Upper	13.7364	172.3241	0.8405	11.3359	0.7146
Mean	5.0452	69.2529	0.4425	4.4535	0.3764

Table 73: Variance of Data and Bootstraps for Weighted Model

	Prod	Cons	Gov	Inv	Price	Wage NC	Wage SW	Taylor Rule	TOTAL
C	26.041	6.513	0.413	2.903	0.068	49.568	0.000	14.494	100
I	13.792	0.054	0.158	34.390	0.003	33.683	0.000	17.920	100
K	20.767	0.033	0.121	18.648	0.002	39.724	0.000	20.706	100
L	22.861	4.391	6.197	2.762	0.033	54.190	0.000	9.566	100
π	1.087	11.414	0.556	0.469	6.091	6.246	0.002	74.135	100
Q	9.344	5.299	1.284	12.582	1.428	43.131	0.001	26.931	100
R	5.141	20.320	2.297	2.421	6.155	27.080	0.011	36.574	100
rk	8.240	32.100	1.832	9.411	0.960	17.745	0.004	29.708	100
W	14.806	36.872	0.182	2.092	1.301	9.770	0.008	34.969	100
Y	24.531	4.518	3.780	3.538	0.052	48.228	0.000	15.352	100

Table 74: Variance Decompositon for Weighted Model

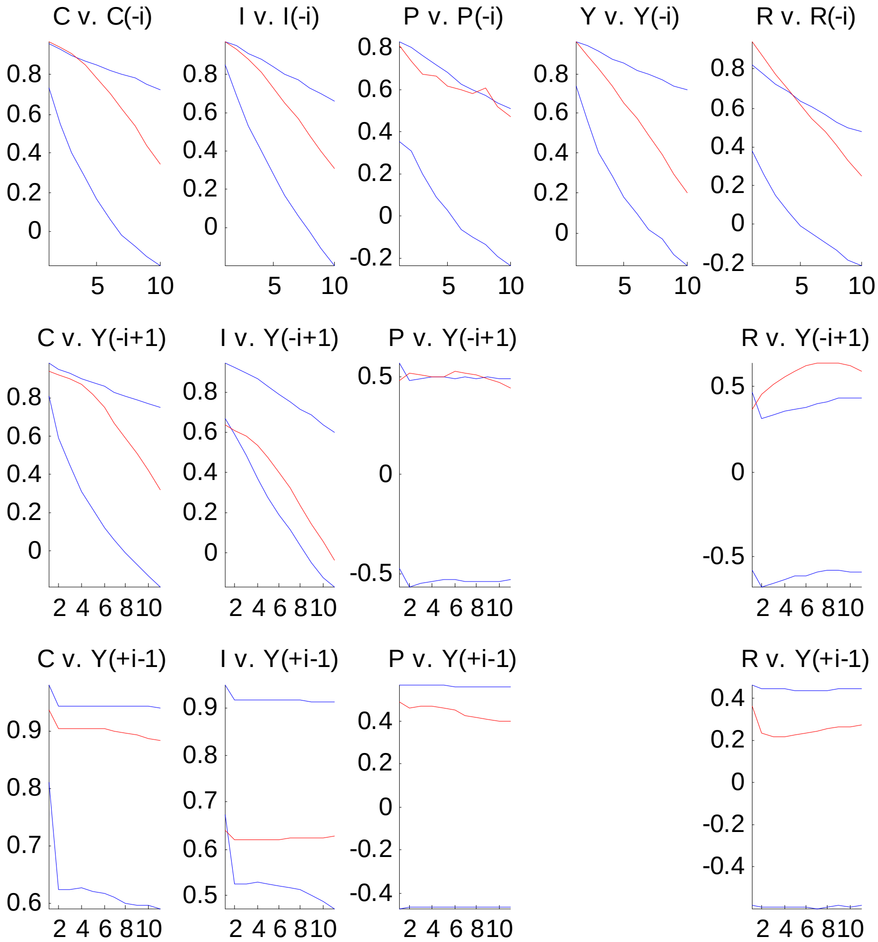

Figure 174: Cross-Correlations for weighted model

O.5 Cross-Correlations for Weighted Model

ABOUT THE CDMA

The **Centre for Dynamic Macroeconomic Analysis** was established by a direct grant from the University of St Andrews in 2003. The Centre funds PhD students and facilitates a programme of research centred on macroeconomic theory and policy. The Centre has research interests in areas such as: characterising the key stylised facts of the business cycle; constructing theoretical models that can match these business cycles; using theoretical models to understand the normative and positive aspects of the macroeconomic policymakers' stabilisation problem, in both open and closed economies; understanding the conduct of monetary/macroeconomic policy in the UK and other countries; analyzing the impact of globalization and policy reform on the macroeconomy; and analyzing the impact of financial factors on the long-run growth of the UK economy, from both an historical and a theoretical perspective. The Centre also has interests in developing numerical techniques for analyzing dynamic stochastic general equilibrium models. Its affiliated members are Faculty members at St Andrews and elsewhere with interests in the broad area of dynamic macroeconomics. Its international Advisory Board comprises a group of leading macroeconomists and, ex officio, the University's Principal.

THE CDMA CONFERENCE 2008, held in St. Andrews, 3th to the 5th of September 2008.

PAPERS PRESENTED AT THE CONFERENCE, IN ORDER OF PRESENTATION:

Title	Author(s) (presenter(s) in bold)
Robust Learning Stability with Operational Monetary Policy Rules	**George Evans (Oregon and St Andrews)** co-authored with Seppo Honkapohja
Who pays for job training?	**Parantap Basu (Durham)**
Electoral Uncertainty and the Deficit Bias in a New Keynesian Economy	**Campbell Leith (Glasgow)**
Sacrifice Ratio or Welfare Gain Ratio? Disinflation in a DGSE monetary model	**Guido Ascari (Pavia)**
Estimating insurance and incentive effects of labour market reforms	**Klaus Waelde (Glasgow)**
Using time-varying VARs to diagnose the source of 'Great Moderations': a Monte Carlo analysis	**Tony Yates (Bank of England)**
The Optimum Quantity of Money with Gold Reserves	**Max Gillman (Cardiff)**
Managing Disinflation Under Uncertainty	**Eric Schaling (Pretoria)**
Factor demand linkages and the business cycle: interpreting aggregate fluctuations as sectoral fluctuations	**Sean Holly (Cambridge)**
Monetary and Fiscal Rules in an Emerging Small Open Economy	**Paul Levine (Surrey)** with joint with Nicoletta Batini (IMF and Surrey) Joe Pearlman (London Met)
Can a pure Real Business Cycle Model explain the real exchange rate?	**Patrick Minford (Cardiff)**
Macroeconomic Implications of a Key Currency	**Matthew Canzoneri (Georgetown)**
How we can model the credit crunch	**Peter Sinclair (Birmingham)**
Sticky information versus efficient indexation	**Richard Mash (New College, Oxford**

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