Data and Estimation Appendix to “MAJA: A two-region DSGE model for Sweden and its main trading partners”

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Abstract

This Appendix contains additional details on data and estimation of the model presented in Corbo and Strid (2020). It also contains some additional results.

Contents

1 Data

1.1 Sample period, vintage and transformations

The DSGE model MAJA is estimated using 25 data series, 10 foreign data series and 15 Swedish series. The sample period used for estimation and other analysis in the paper is 1995Q2–2018Q4, which means the sample length is 95 quarters. The vintage of the data is April 25, 2019, i.e. the dataset was constructed based on the data available in the Riksbank's internal database Doris at this date. The transformations applied to the data series are described in the working paper and are also summarised in Table 7 below. Foreign (KIX20-weighted) and Swedish GDP and its components — consumption, investment, exports and imports — are transformed into annualised quarterly per capita growth rates expressed in percent. The price and wage series and the Swedish real exchange rate are transformed into annualised quarterly changes in percent. The foreign and Swedish employment rates are transformed into gaps, which are measured in percentage deviations from trend. The foreign and Swedish unemployment rates, policy rates and corporate spreads and Swedish capacity utilization are not transformed.

1.2 Data sources

In Table 1 the Statistical Data and Metadata Exchange (SDMX) codes of the 25 data series used in estimation and, in addition, two population series are listed. The SDMX code refers to the code of the data series in the Riksbank's database Doris. Information on the source agency, e.g. Statistics Sweden (SCB) in the case of Swedish GDP, is provided through the metadata in the database. The superscript *obs* denotes that the variable is observed and the superscript "$*$" means that it is a foreign variable.

The foreign and domestic population series are used to transform a subset of the observed variables into per capita terms. All data series except the policy rates and corporate spreads are seasonally adjusted. The KIX20-weighted foreign data series are a trade weighted average of data series for the euro area and the United States (US) which is constructed by the Riksbank.[1] The euro area data consists of data for the 19 countries in the monetary union. While the KIX-weights are time-varying the euro area weight in the KIX20-index has been fairly stable around 85% in the sample period, and hence the US weight has been around 15%. The SDMX codes and source agencies of the underlying euro area and US data series used to construct the KIX20-weighted data are reported in Tables 2 and 3.

Next the Swedish data series used in the estimation of MAJA and their sources are described. Capacity utilization (CU_t) is the utilized production capacity in the manufacturing industry in percent, from the Business tendency survey of the National Institute of Economic Research (NIER). GDP (Y_t^{obs}), private consumption (C_t^{obs}), gross fixed capital formation (I_t^{obs}), exports of goods and services (X_t^{obs}), and imports of goods and services (M_t^{obs}) are from the national accounts (Statistics Sweden, SCB). These variables are deflated using the respective price deflator. The variables are transformed into per capita terms using the population aged 15-74 (POP_t) from the Labor force survey (Statistics Sweden, SCB), and are then transformed into annualised quarterly growth rates. The price indices CPIF ($\pi_t^{c,obs}$) and CPIF excluding energy ($\pi_t^{cxe,obs}$) are provided by Statistics Sweden and they are transformed into annualised quarterly inflation rates. The construction of the measure of import inflation ($\pi_t^{m,cxe,obs}$) is discussed in the working paper. It contains the goods and services in the CPI which are classified as mostly imported and it excludes imported energy goods. To a large extent it overlaps with the CPI goods component.

[1] Sometimes the KIX20-index is alternatively referred to as the KIX2-index, where the difference is that the former counts the euro area countries individually. KIX is short for 'krona index'. The KIX weights were previously calculated by the National Institute for Economic Research, NIER. In accordance with an agreement between the Riksbank and NIER, the Riksbank took over the responsibility for calculating KIX weights from 2016.

Table 1: Foreign (KIX20) and Swedish data series used for estimation of MAJA. Statistical Data and Metadata Exchange (SDMX) codes in the Riksbank's database Doris.

Variable		SDMX code
Foreign (KIX20)		
Consumption	$\Delta C_t^{*,obs}$	ESA1.Q.RB_KIX2.Y.1415.P30000.0000.TTTT.Q.N.A.OUTC.NA
CPI	$\pi_t^{c,*,obs}$	ICP1.Q.RB_KIX2.Y.RB_S000000.2.INX.OUTC.NA
CPI excl. energy	$\pi_t^{*,cxe,obs}$	ICP1.Q.RB_KIX2.Y.RB_CPIXE.2.INX.OUTC.NA
Empl. rate 15-74	$N_t^{*,gap,obs}$	STS1.Q.RB_KIX2.Y.RB_EM.RB_LTT002.1.RB_PCT.OUTC.NA
GDP	$\Delta Y_t^{*,obs}$	ESA1.Q.RB_KIX2.Y.0000.B1QG00.1000.TTTT.Q.N.A.OUTC.NA
Investment	$\Delta I_t^{*,obs}$	ESA1.Q.RB_KIX2.Y.1000.P51000.0000.TTTT.Q.N.A.OUTC.NA
Policy rate	$R_t^{*,obs}$	FMD2.Q.RB_KIX2.SEK.RB_TR.RB_KR.RB_ED.HSTA.OUTC.NA
Corporate spread	$SPR_t^{*,obs}$	FMD2.Q.RB_KIX2.SEK.RB_TR.SP.RB_ED.HSTA.OUTC.NA
Unempl. rate, 15-74	$U_t^{*,obs}$	STS1.Q.RB_KIX2.Y.RB_UR.RB_LTT002.1.ABS.OUTC.NA
Wage	$\Delta W_t^{*,obs}$	ESA1.Q.RB_KIX2.RB_CA.1000.COMEMP.0000.TTTT.V.N.A.OUTC.NA
Population	POP_t^*	ESA1.Q.SE.Y.0000.POPULA.1000.RB_T1574.N.P.A.OUTC.NA
Sweden		
Capacity utilization	CU_t	SUR1.Q.SE.S.RB_KI_BTS.RB_MAN_104.RB_010000.NETVAL_XP.NA
Consumption	ΔC_t^{obs}	ESA1.Q.SE.Y.1415.P31000.0000.TTTT.Y.N.A.OUTC.LS
CPIF	$\pi_t^{c,obs}$	ICP1.Q.SE.Y.RB_FS000000.1.INX.OUTC.NA
CPIF excl. energy	$\pi_t^{cxe,obs}$	ICP1.Q.SE.Y.RB_XEFS000000.1.INX.OUTC.NA
CPIF imp. excl. ene.	$\pi_t^{m,cxe,obs}$	ICP1.Q.SE.Y.RB_S200000XE.1.INX.OUTC.NA
Empl. rate. 15-74	$N_t^{gap,obs}$	STS1.Q.SE.Y.EMPL.RB_LTT002.1.RB_GK.OUTC.NA
Exports	ΔX_t^{obs}	ESA1.Q.SE.Y.2000.P60000.0000.TTTT.Y.N.A.OUTC.LS
GDP	ΔY_t^{obs}	ESA1.Q.SE.Y.0000.B1QG00.1000.TTTT.Y.N.A.OUTC.LS
Imports	ΔM_t^{obs}	ESA1.Q.SE.Y.0000.P70000.2000.TTTT.Y.N.A.OUTC.LS
Investment	ΔI_t^{obs}	ESA1.Q.SE.Y.1000.P51000.0000.TTTT.Y.N.A.OUTC.LS
Real exch. rate	ΔQ_t^{obs}	EXR1.Q.SEK.RB_KIX2.ERC0.A.OUTC.NA
Policy rate	R_t^{obs}	FMD2.Q.SE.SEK.RB_TR.RB_KR.RB_ED.HSTA.OUTC.NA
Corporate spread	SPR_t^{obs}	FMD2.Q.SE.SEK.RB_TR.SP.RB_ED.HSTA.OUTC.NA
Unempl. rate, 15-74	U_t^{obs}	STS1.Q.SE.Y.RB_UR.RB_LTT002.1.ABS.OUTC.LS
Wage (KL)	ΔW_t^{obs}	STS1.Q.SE.S.WAGE.000000.5.LEV.OUTC.NA
Population, 15-74	POP_t	STS1.Q.RB_KIX2.N.RB_POP.RB_LTT002.1.RB_INX.OUTC.NA

Table 2: Euro area data series. Statistical Data and Metadata Exchange (SDMX) codes and source agencies in the Riksbank's database Doris.

Variable		SDMX code	Agency
Cons.	$\Delta C_t^{*,obs}$	ESA1.Q.U2.Y.0000.P30000.1000.TTTT.Q.N.A.OUTC.NA	MB
HICP	$\pi_t^{c,*,obs}$	ICP1.Q.U2.Y.000000.3.INX.OUTC.NA	ES
HICP excl. energy	$\pi_t^{cxe,*,obs}$	ICP1.Q.U2.Y.XE0000.3.INX.OUTC.NA	ECB
Empl. rate, 15-74	$N_t^{*,obs,gap}$	STS1.Q.U2.S.RB_EM.RB_RTT002.1.RB_PCT.OUTC.NA	ES
GDP	$\Delta Y_t^{*,obs}$	ESA1.Q.U2.Y.0000.B1QG00.1000.TTTT.Q.N.A.OUTC.LS	ES
Invest.	$\Delta I_t^{*,obs}$	ESA1.Q.U2.Y.1000.P51000.0000.TTTT.Q.N.A.OUTC.NA	ES
EONIA	$R_t^{*,obs}$	FMD2.Q.U2.EUR.RB_MB.MM.RB_ON.RB_FIX.OUTC.LS	R
Corporate spread	$SPR_t^{*,obs}$	FMD2.Q.U2.SEK.RB_TR.SP.RB_ED.HSTA.OUTC.NA	RB
Unempl. rate, 15-74	$U_t^{*,obs}$	STS1.Q.U2.S.RB_UR.RB_RTT002.4.RB_PCT.OUTC.NA	ES
Comp. per empl.	$\Delta W_t^{*,obs}$	ESA1.Q.U2.Y.1000.COMEMP.0000.TTTT.V.RB_NORM.A.OUTC.NA	MB
Pop 15-74	POP_t^{*}	STS1.Q.U2.N.RB_POP.RB_LTT002.1.ABS.OUTC.NA	ES

Note: MB: Macrobond. ES: Eurostat. ECB: European central bank. R: Reuters. RB: Riksbank.

Table 3: United States data series. Statistical Data and Metadata Exchange (SDMX) codes and source agencies in the Riksbank's database Doris.

Variable		SDMX code	Agency
Cons.	$\Delta C_t^{*,obs}$	ESA1.Q.US.S.0000.P30000.1000.TTTT.Q.RB_D.A.OUTC.NA	MB
CPI	$\pi_t^{c,*,obs}$	ICP1.Q.US.S.RB_CPI000000.1.INX.OUTC.NA	BLS
CPI excl. energy	$\pi_t^{cxe,*,obs}$	ICP1.Q.US.S.RB_USXE000.1.INX.OUTC.NA	BLS
Empl. rate, 16-74	$N_t^{*,obs,gap}$	STS1.Q.US.S.RB_EM.RB_RTT002.1.RB_PCT.OUTC.NA	BLS
GDP	$\Delta Y_t^{*,obs}$	ESA1.Q.US.Y.0000.B1QG00.1000.TTTT.Q.N.A.OUTC.NA	BEA
Invest.	$\Delta I_t^{*,obs}$	ESA1.Q.US.Y.1000.P51000.0000.TTTT.Q.N.A.OUTC.NA	MB
Fed funds rate	$R_t^{*,obs}$	FMD2.Q.US.USD.RB_MB.RB_ER.RB_FFR.RB_CLOSE.OUTC.NA	FR
Corporate spread	$SPR_t^{*,obs}$	MIR1.Q.US.B.A2AC.A.R.A.2240.USD.O.OUTC.NA*	FR
Unempl. rate, 16-74	$U_t^{*,obs}$	STS1.Q.US.S.UNEH.RB_RTT002.5.RB_PCT.OUTC.NA	BLS
Comp. per empl.	$\Delta W_t^{*,obs}$	ESA1.Q.US.S.1000.COMEMP.0000.TTTT.V.N.A.OUTC.NA	MB
Pop 16-74	POP_t^{*}	STS1.Q.US.S.RB_POP.RB_LTT002.1.ABS.OUTC.NA	BLS

Note: MB: Macrobond. BEA: Bureau of Economic Analysis. BLS: Bureau of Labor Statistics. FR: Federal Reserve. * The SDMX code refers to the corporate interest rate used to compute the spread.

The construction of the employment gap ($N_t^{obs,gap}$) is described in the working paper. It is the percent deviation of employment in the age 15-74 from the KAMEL trend for employment. The unemployment rate (U_t^{obs}) is the fraction of unemployed persons in the labour force in the ages 15-74 (Statistics Sweden). Wages (W_t^{obs}) are the wages according to the short-term wage statistics provided by the National Mediation Office (in Swedish 'konjunkturlöner'). The wage series is transformed into annualised quarterly wage inflation. The real exchange rate (Q_t^{obs}) is based on the nominal KIX20 exchange rate index, Swedish CPIF and KIX20 CPI and it is transformed into annualised quarterly changes. The policy interest rate (R_t^{obs}) is the Riksbank repo rate. The corporate spread (SPR_t^{obs}) is computed as the difference between a short maturity interest rate on banks' loans to non-financial corporations (for which the SDMX code is MIR1.Q.SE.RB_BA.RB_A20L.A.R.A.2240.SEK.O.OUTC.NA in the database Doris) and the repo rate.

The euro area data series used to construct the KIX20-weighted series are as follows. GDP ($Y_t^{*,obs}$), private consumption expenditure ($C_t^{*,obs}$) and gross fixed capital formation ($I_t^{*,obs}$) are provided by Eurostat. These variables are deflated using the respective price deflator and are transformed into per capita terms using the population (POP_t^*) aged 15-74 from the labour force survey by Eurostat. The variables are transformed into annualised quarterly growth rates. The construction of the employment gap ($N_t^{*,gap,obs}$) is discussed in the working paper. Note that the trend which is used to construct the gap is computed for the KIX20-weighted employment rate as described in the working paper. The definition of employment is employed persons in the ages 15-74 and the same age group is used for the unemployment rate ($U_t^{*,obs}$). The price indices HICP ($\pi_t^{c,*,obs}$) and HICP excluding energy ($\pi_t^{cxe,*,obs}$) are obtained from Eurostat and the ECB, respectively. The measure of wages ($W_t^{*,obs}$) is the total economy compensation per employee. The price and wage indices are transformed into annualised quarterly changes. The policy rate ($R_t^{*,obs}$) is the EONIA rate. The corporate spread ($SPR_t^{*,obs}$) is the difference between the interest rate on MFI's loans to non-financial corporations (SDMX code MIR1.Q.U2.B.A2A.A.R.A.2240.EUR.N.OUTC.NA in Doris) and the EONIA rate.

The US variables used to construct the KIX20-weighted variables are as follows. Chain-weighted GDP ($Y_t^{*,obs}$), personal consumption expenditures ($C_t^{*,obs}$) and gross fixed capital formation ($I_t^{*,obs}$) are deflated using the respective price deflator and transformed into per capita terms using the population (POP_t^*) aged 15-74 from the Labor force survey. These variables are transformed into annualised quarterly growth rates. Employment ($N_t^{*,obs,gap}$) and the unemployment rate ($U_t^{*,obs}$) are defined for the age group 16-74 years and the source is the Bureau of Labor Statistics (BLS). CPI ($\pi_t^{c,*,obs}$), CPI excluding energy ($\pi_t^{cxe,*,obs}$) and compensation per employee for civilian workers ($W_t^{*,obs}$) are transformed into annualised quarterly changes. The policy rate ($R_t^{*,obs}$) is the Federal funds rate (FFR). The corporate spread is the difference between a corporate interest rate (with SDMX code MIR1.Q.US.B.A2AC.A.R.A.2240.USD.O.OUTC.NA) and the FFR.

1.3 Outliers

The following observations are treated as outliers: euro area consumption in 2014Q1, euro area investment in 2015Q2 and 2015Q3, and euro area GDP in 2014Q1 and 2015Q1. For these variables and dates the observation has been replaced by an interpolated value. All analysis in the paper is based on the 'outlier-corrected' dataset.

1.4 Swedish GDP ratios

In Figure 1, ratios of Swedish nominal (i.e. current prices) consumption, investment, exports, imports and government consumption to nominal GDP are displayed. Note that the data series used in these graphs have not been seasonally adjusted. The average ratios in the period 1995–2018 are indicated with red (dotted) lines. These ratios are used to calibrate the corresponding ratios in the model; see the discussion on the calibrations of the expenditure shares in the working paper. In particular, note that the average export ratio exceeds the average import ratio, reflecting an average surplus in the trade balance in the sample period. As a consequence, the sum of the average consumption, investment and government consumption ratios is around 0.94, i.e. significantly below 1, in the sample period. In the model the trade balance as a share of GDP is calibrated close to zero and the consumption, investment and government consumption ratios are consequently calibrated to larger values than the average ratios in the data such that these ratios sum to a value close to 1 in the model.

In Figure 2, the corresponding real (i.e. fixed prices) ratios are displayed. These graphs can be used to roughly assess the trend assumptions in the model. (Note that the numbers on the y-axis in these graphs have no interpretation.) We note that average consumption growth has been similar to average GDP growth while investment, exports and imports have on average grown faster than GDP in the period 1995–2018, i.e. the real ratios of these variables to GDP are trending upwards. This motivates the incorporation of additional excess trend for these variables; see the working paper and also the discussion below for a description of the excess trends.

1.5 Contemporaneous correlations between observed variables

The data series used for estimation are displayed in the working paper where their means and standard deviations in the sample period are also reported. The contemporaneous bivariate correlations between the observed variables in the estimation dataset are reported in Table 4 (correlations among foreign variables, $\frac{10*9}{2} = 45$ variable pairs), Table 5 (correlations among domestic variables, 105 pairs) and Table 6 (correlations between domestic and foreign variables, 150 pairs). Note that these sample correlations are computed for the observed variables in the formats they enter the estimation dataset. One may note that correlations between variables expressed as annual growth rates are usually larger than the correlations between variables expressed as (annualised) quarterly growth rates. One should also note that to study empirical relationships between variables using cross-correlations it is typically preferable to apply the same transformations to the variables. For example, the rather strong empirical relationship between GDP and labour market variables is not readily apparent from these tables since GDP is transformed into an annualised quarterly growth rate while employment and unemployment instead enter in levels.

2 The empirical model

2.1 Observed variables' steady states and excess trends

In this section, we provide further detail on the assumed excess trends/parameters in the model, the steady states of the observed variables and their individual observation equations. The observation equation is given by

$$Y_t = c_t + d(\theta) + ZX_t + v_t,\ t = 1, ..., T \ , \tag{2.1}$$

where Y_t is the vector of observed variables, X_t is the vector containing all the variables in the DSGE model, and v_t is the vector of observation errors.[2] The DSGE model-implied steady state of the observed variables is given by $d(\theta)$ while the (possibly) time-varying parameter vector c_t contains the excess parameters which are introduced to better align the model steady state to the data sample means of the variables. The introduction of c_t is motivated in the working paper and the overall purpose is to make the model more empirically realistic. The steady-state assumptions are collected in Table 7 where we separately report the DSGE model-implied steady state of the vector of observed variables, d, and the steady state of the observed variables in the empirical model taken to the data, $d + c_t$. For the foreign and domestic corporate spreads and domestic capacity utilization the DSGE model-implied steady states are zero and the intercepts in the observation equations are therefore calibrated directly based on the sample data. For domestic exports and imports the excess parameter in the latter part of the sample is reported in the table, while a full description of the excess trend/parameter is provided below.

[2] While the state vector X_t could be defined in alternative ways, for simplicity we assume it contains all variables.

Figure 1: Swedish nominal GDP ratios, 1980Q1–2018Q4.

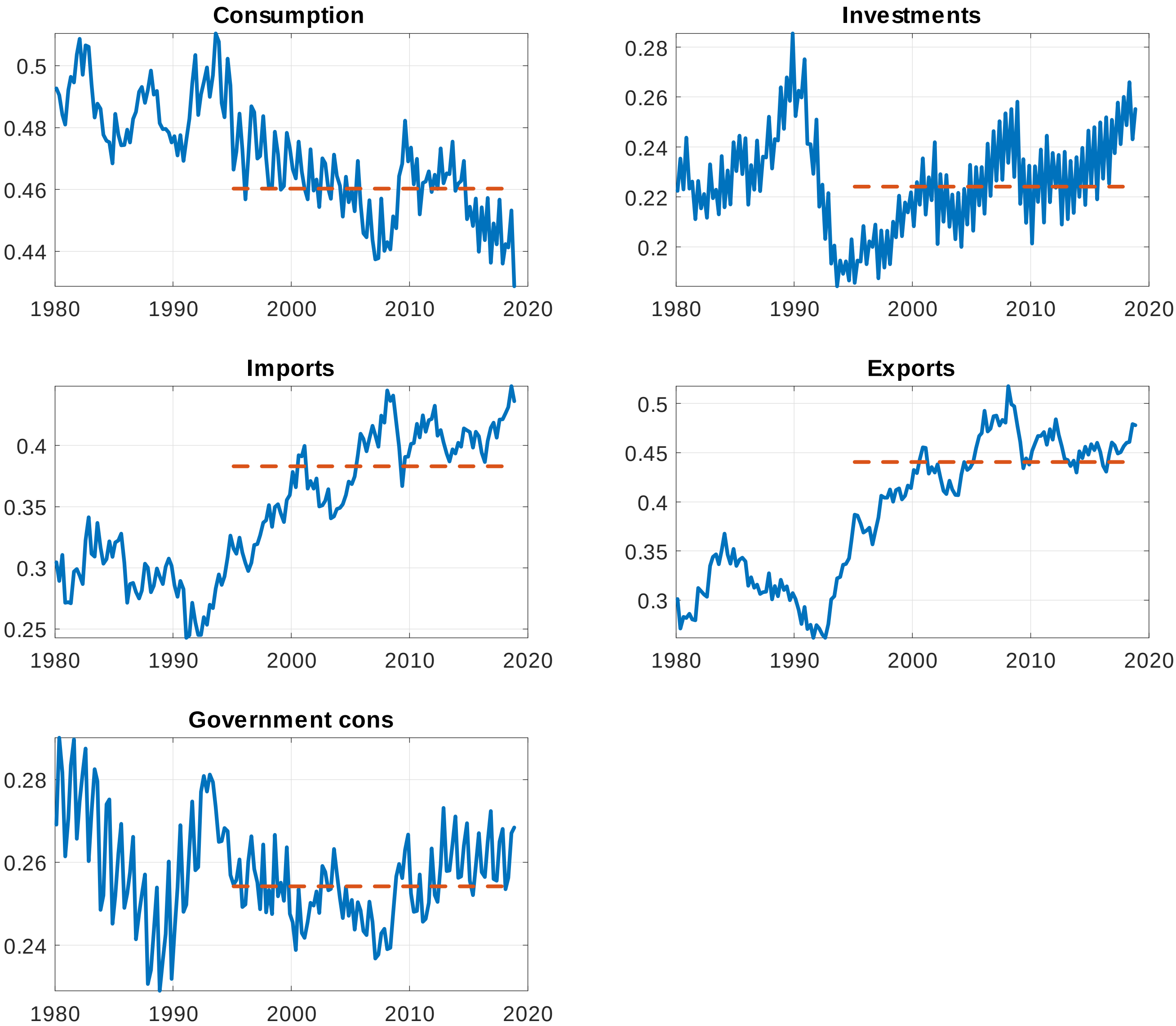


Figure 2: Swedish real GDP ratios, 1980Q1–2018Q4.

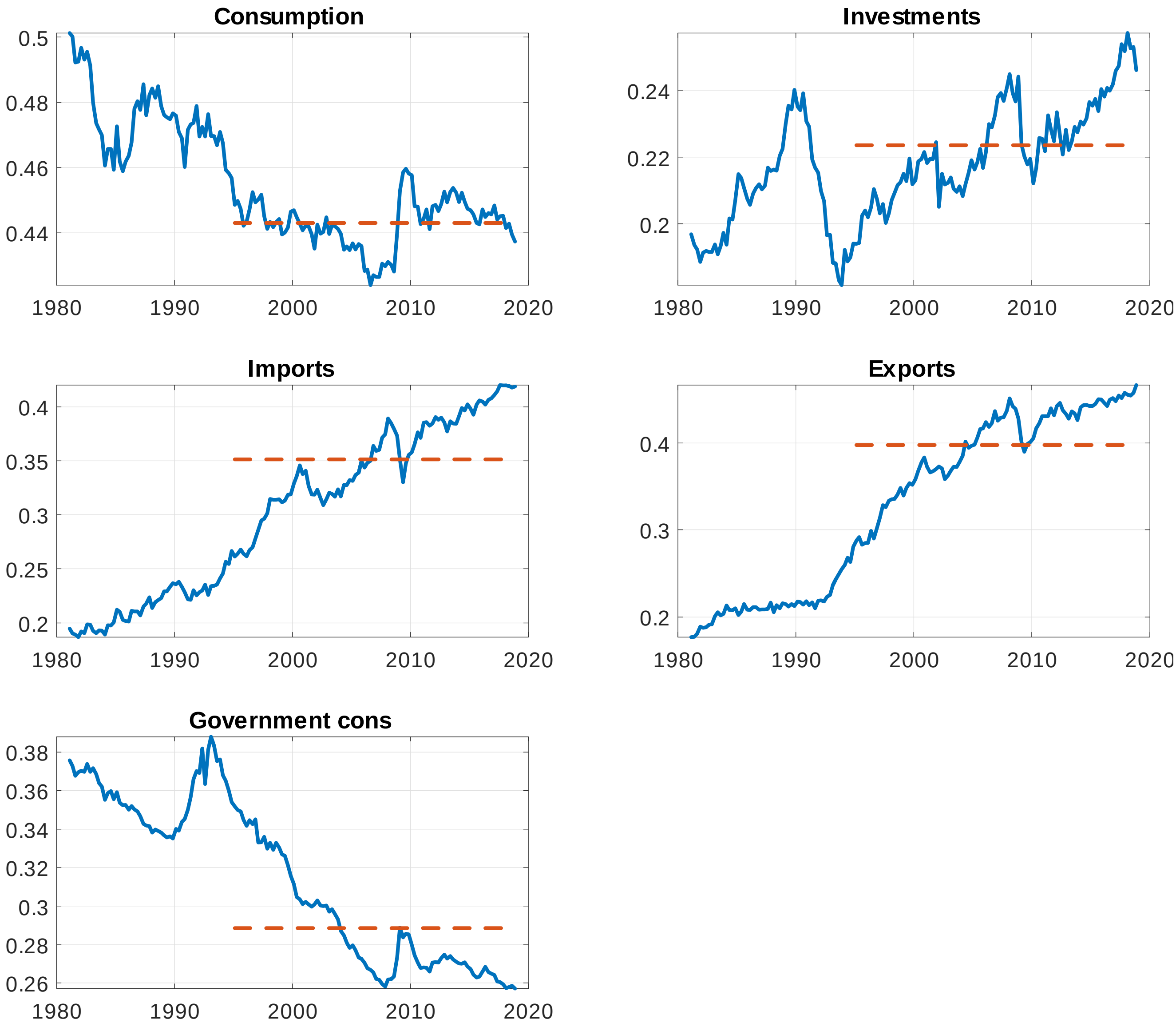


Table 4: Contemporaneous sample correlations between foreign (KIX20-weighted) variables.

Variable	1	2	3	4	5	6	7	8	9	10
1. $\Delta C_t^{*,obs}$	1.00									
2. $\pi_t^{c,*,obs}$	-0.06	1.00								
3. $\pi_t^{cxe,*,obs}$	-0.17	0.60	1.00							
4. $N_t^{*,obs,gap}$	0.02	0.32	0.39	1.00						
5. $\Delta Y_t^{*,obs}$	0.71	0.23	-0.10	-0.04	1.00					
6. $\Delta I_t^{*,obs}$	0.60	0.16	-0.07	-0.04	0.82	1.00				
7. $R_t^{*,obs}$	0.26	0.30	0.58	0.45	0.13	0.10	1.00			
8. $SPR_t^{*,obs}$	-0.31	-0.34	-0.56	-0.90	-0.18	-0.14	-0.84	1.00		
9. $U_t^{*,obs}$	-0.03	-0.28	-0.32	-0.95	0.01	0.01	-0.32	0.84	1.00	
10. $\Delta W_t^{*,obs}$	0.16	0.51	0.47	0.50	0.21	0.17	0.45	-0.57	-0.46	1.00

Table 5: Contemporaneous sample correlations between Swedish variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. CU_t	1.00														
2. ΔC_t^{obs}	0.09	1.00													
3. $\pi_t^{c,obs}$	0.10	-0.04	1.00												
4. $\pi_t^{cxe,obs}$	-0.17	-0.09	0.66	1.00											
5. $\pi_t^{m,cxe,obs}$	-0.23	0.05	0.45	0.66	1.00										
6. $N_t^{obs,gap}$	0.22	-0.23	0.23	0.21	-0.01	1.00									
7. ΔX_t^{obs}	0.38	0.22	-0.02	-0.24	-0.05	-0.24	1.00								
8. ΔY_t^{obs}	0.38	0.50	0.11	-0.08	0.10	-0.21	0.65	1.00							
9. ΔM_t^{obs}	0.38	0.28	-0.08	-0.22	-0.08	-0.29	0.70	0.51	1.00						
10. ΔI_t^{obs}	0.36	0.11	-0.05	-0.20	-0.02	-0.14	0.40	0.49	0.38	1.00					
11. ΔQ_t^{obs}	-0.09	-0.18	-0.15	-0.01	-0.04	0.15	-0.18	-0.39	-0.31	-0.18	1.00				
12. R_t^{obs}	0.20	0.03	0.09	0.05	0.07	-0.26	-0.06	-0.02	-0.07	0.05	-0.06	1.00			
13. SPR_t^{obs}	-0.27	0.03	-0.18	-0.11	-0.03	-0.43	0.16	0.07	0.20	0.01	0.02	-0.49	1.00		
14. U_t^{obs}	-0.19	0.21	-0.19	-0.19	0.02	-0.98	0.23	0.20	0.26	0.11	-0.13	0.33	0.41	1.00	
15. ΔW_t^{obs}	0.09	0.03	0.14	0.09	0.18	-0.17	0.01	-0.09	-0.12	-0.11	-0.01	0.71	-0.37	0.23	1.00

Table 6: Contemporaneous sample correlations between Swedish (column) and foreign, KIX20-weighted, (row) variables.

Dom/for	$\Delta C_t^{*,o}$	$\pi_t^{c,*,o}$	$\pi_t^{cxe,*,o}$	$N_t^{*,gap,o}$	$\Delta Y_t^{*,o}$	$\Delta I_t^{*,o}$	$R_t^{*,o}$	$SPR_t^{*,o}$	$U_t^{*,o}$	$\Delta W_t^{*,o}$
CU_t	0.39	0.49	0.32	0.46	0.54	0.59	0.35	-0.49	-0.53	0.38
ΔC_t^{obs}	0.52	-0.03	-0.15	-0.06	0.41	0.24	0.09	-0.02	0.11	0.01
$\pi_t^{c,obs}$	-0.09	0.40	0.24	0.27	-0.03	-0.10	0.12	-0.30	-0.31	0.29
$\pi_t^{cxe,obs}$	-0.18	-0.10	0.07	0.15	-0.25	-0.28	0.07	-0.19	-0.20	0.03
$\pi_t^{m,cxe,obs}$	0.03	-0.19	-0.10	0.00	-0.07	-0.11	0.09	-0.11	-0.03	0.06
$N_t^{obs,gap}$	-0.25	0.12	0.14	0.63	-0.22	-0.18	-0.21	-0.66	-0.72	0.24
ΔX_t^{obs}	0.45	0.21	-0.11	-0.12	0.62	0.58	0.01	0.00	0.12	0.09
ΔY_t^{obs}	0.55	0.21	-0.12	-0.09	0.68	0.54	0.07	-0.11	0.10	0.07
ΔM_t^{obs}	0.42	0.13	-0.15	-0.16	0.66	0.63	0.00	0.06	0.15	0.07
ΔI_t^{obs}	0.32	0.10	-0.05	-0.05	0.50	0.47	0.09	-0.09	0.05	0.07
ΔQ_t^{obs}	-0.03	-0.28	-0.06	0.09	-0.35	-0.19	0.03	-0.10	-0.14	0.01
R_t^{obs}	0.11	0.31	0.65	0.28	-0.02	-0.01	0.92	-0.66	-0.13	0.40
SPR_t^{obs}	-0.01	-0.30	-0.48	-0.84	0.10	0.11	-0.58	0.86	0.73	-0.43
U_t^{obs}	0.24	-0.09	-0.08	-0.59	0.21	0.16	-0.27	0.68	0.67	-0.19
ΔW_t^{obs}	0.10	0.27	0.46	0.22	0.00	-0.09	0.68	-0.50	-0.14	0.27

The excess trends are discussed in the working paper and here we provide additional details. The steady-state annual global productivity growth rate is assumed to be $400\ln(\mu_{z+}^*) = 1.3\%$, which is in line with the sample average of foreign GDP per capita growth. The assumption of balanced growth then implies that this is the steady-state growth rate of foreign per capita GDP, consumption and investment, i.e. $\Delta Y^* = \Delta C^* = \Delta I^* = 400\ln(\mu_{z+}^*)$.[3] The assumed steady-state per capita growth rate is lower than the pre-financial crisis sample mean GDP per capita growth rate but higher than the post-financial crisis mean. Note again that the sample mean and standard deviation of the observed variables are reported in the working paper.

The steady-state foreign inflation rate is calibrated as $\pi^{*,c,obs} = \pi^{*,cxe,obs} = \pi^{*,obs} = 400\ln(\pi^*) = 2.0\%$ which is motivated by the inflation targets of the European Central Bank and the Federal Reserve. The steady-state foreign nominal policy interest rate is assumed to be given by

$$\begin{aligned} R^{*,obs} &= d^{R^*} + c^{R^*} = 400\ln(\mu_{z+}^*) + 400\ln(\pi^*) - 400\ln(\beta^*) + c^{R^*} = \\ &= 1.3 + 2.0 - (-0.4) - 0.7 = 3.0\%, \end{aligned}$$

where $c^{R^*} = -0.7$ percentage points is an excess parameter which has been calibrated to decrease the model-implied steady-state foreign policy rate of $d^{R^*} = 3.7\%$ to $R^{*,obs} = d^{R^*} + c^{R^*} = 3.0\%$. The foreign and Swedish discount rates are calibrated to the same value, $\beta^* = \beta = 0.999$. This value is obviously high and it is motivated by the effects on the steady-state foreign and domestic real policy interest rates, i.e. lower values of β^* and/or β would imply higher model-implied steady-state interest rates. For example, calibrating $\beta^* = \beta = 0.995$ instead of $\beta^* = \beta = 0.999$ would increase the DSGE model steady-state interest rates by 1.6 percentage points since $400\ln(0.995) = -2.0$. But this is difficult to reconcile with the very low interest rates in, say, the past 10 years. The excess parameter c^{R^*} cannot be identified from the data since the interest rate is downward trending, i.e. it displays unit root behaviour, and attempts to estimate the parameter are therefore fruitless. Its value is chosen such that the steady-state policy rate is broadly in line with central banks', mainly Federal Reserve's,

[3] To simplify the notation for the steady state values of the observed variables and the excess trend parameters the superscript 'obs' is sometimes dropped here, e.g. $\Delta Y^{*,obs} = \Delta Y^*$.

Table 7: DSGE model steady state (d), excess trends (c) and steady state of observed variables in the empirical model (d+c).

		Data	Model steady state		
		Mean	DSGE model	Excess	Empirical model
Variable	Transf. and unit	95Q2–18Q4	d	c	$d+c$
Foreign (KIX20)					
Consumption	Per cap, 4qq, perc	1.2	1.3	0.0	1.3
CPI	4qq, perc	1.8	2.0	0.0	2.0
CPI excluding energy	4qq, perc	1.7	2.0	0.0	2.0
Employment	Per cap, perc	-1.6	0.0	0.0	0.0
GDP	Per cap, 4qq, perc	1.3	1.3	0.0	1.3
Investment	Per cap, 4qq, perc	1.5	1.3	0.0	1.3
Policy rate	Perc	2.2	3.7	-0.7	3.0
Corporate spread	Perc points	1.8	0.0	1.8	1.8
Unemployment rate	Perc	9.0	8.0	0.0	8.0
Wage	4qq, perc	2.2	3.3	-0.8	2.5
Sweden					
Capacity utilization	Perc	83.8	0.0	85.0	85.0
Consumption	Per cap, 4qq, perc	1.7	1.6	0.15	1.7
CPIF	4qq, perc	1.5	2.0	0.0	2.0
CPIF excl. energy	4qq, perc	1.3	2.0	0.0	2.0
CPIF imp. excl. energy	4qq, perc	-0.4	2.0	-2.0	0.0
Employment	Per cap, perc	-0.8	0.0	0.0	0.0
Exports	Per cap, 4qq, perc	2.7	1.6	0.15+1.0	2.7
GDP	Per cap, 4qq, perc	1.8	1.6	0.15	1.7
Imports	Per cap, 4qq, perc	2.7	1.6	0.15+1.0	2.7
Investment	Per cap, 4qq, perc	2.8	1.6+0.8	0.15	2.5
Real exchange rate	4qq, perc	0.7	0.0	0.0	0.0
Policy rate	Perc	2.4	4.0	-1.0	3.0
Corporate spread	Perc points	1.8	0	1.8	1.8
Unemployment rate	Perc	7.6	7.2	0.0	7.2
Wage	4qq, perc	3.3	3.6	0.15	3.7

Note: Per cap = per capita. Perc = percent. 4qq=annualised quarterly change.

assessment of the long-run policy rate.[4]

Average Swedish GDP per capita growth has been higher than average foreign growth in the sample period. We account for this partly by allowing for deterministic drift, μ_Ψ, in Swedish investment-specific technology growth but also through an additional excess parameter, $c^{\Delta Y}$. Note that since the domestic unit root investment-specific technology shock is not active in the baseline model, i.e. $\hat{\mu}_{\Psi,t} = 0$, the parameter μ_Ψ can equivalently be thought of as an 'excess parameter'. We calibrate this parameter to account for the difference in the sample averages of Swedish GDP and investment growth. The calibrated value $\mu_\Psi = 1.002 > 1$ also implies that Swedish steady-state GDP per capita growth becomes higher than foreign GDP per capita growth. Next, we also allow for the excess parameter $c^{\Delta Y}$ to capture the *remaining difference* between average Swedish and foreign GDP per capita growth in the sample. In summary, Swedish steady-state GDP per capita growth is then assumed to be given by

$$\begin{aligned}\Delta Y &= d^{\Delta Y} + c^{\Delta Y} = 400\ln(\mu_z) + \frac{\alpha}{1-\alpha}400\ln(\mu_\Psi) + c^{\Delta Y} = \\ &= 1.3 + \frac{0.25}{1-0.25}0.8 + 0.15 = 1.3 + 0.27 + 0.15 = 1.7\%,\end{aligned}$$

i.e. it is assumed that the steady-state GDP per capita growth rate of Sweden is $\Delta Y - \Delta Y^* = 0.4$ percentage points higher than the foreign per capita growth rate. The domestic capital share, $\alpha = 0.25$, has been calibrated to target a steady-state domestic investment-output ratio of 24%; see the discussion on the calibration of expenditure shares in the working paper. The resulting assumed steady-state Swedish per capita GDP growth is lower than the pre-financial crisis sample mean but higher than the post-financial crisis mean.

The steady-state Swedish inflation rate is $\pi^{c,obs} = \pi^{cxe,obs} = \pi^{obs} = 400\ln(\pi) = 2.0\%$, which is the inflation target of the Riksbank. The steady-state repo rate is assumed to be

$$\begin{aligned}R^{obs} &= d^R + c^R = 400\ln(\mu_z) + \frac{\alpha}{1-\alpha}400\ln(\mu_\Psi) + 400\ln(\pi) - 400\log(\beta) + c^R = \\ &= 1.57 + 2.0 - (-0.4) - 1.0 = 3.0\%,\end{aligned}$$

which is close to the midpoint of the interval for the long-run repo rate published by the Riksbank in 2017; see Sveriges Riksbank (2017). The excess trend $c^R = -1.0$ decreases the model-implied steady state of $d^R = 4.0$ percent to $d^R + c^R = 3.0$ percent. Note that we have chosen to calibrate identical steady states for the real and nominal interest rates for the foreign economy and Sweden, while the average productivity and GDP per capita growth rates differ. Thus we choose to relax the assumption of a tight steady-state relationship between productivity growth and the real interest rate which is a standard feature of this class of DSGE models. Again, it should be noted that the interest rate excess parameters are not identified by the data due to the trend decline in interest rates.

Average wage growth in the foreign economy has been remarkably low in the sample period, which is also reflected in a downward trend in the foreign labour share. We assume that steady-state foreign real wage growth equals $\Delta w^* = \Delta Y^* + c^{\Delta w^*} = 1.3 - 0.8 = 0.5\%$, which is implemented through a deterministic excess parameter which equals $c^{\Delta w^*} = -0.8$ percentage points. Foreign steady-state nominal wage growth then equals a mere $\Delta W^* = \pi^{*,obs} + \Delta w^* = 2.0 + 0.5 = 2.5\%$. An important consideration here has been to obtain a model-implied measure (i.e. a smoothed estimate) of foreign real marginal costs which is largely stationary.[5] In Sweden, on the other hand, the labour share has

[4] Note that both the foreign and Swedish policy rates display non-stationary behaviour in our sample. Therefore it is not possible to estimate the excess parameters, c^R and c^{R^*}. Instead they are determined such that the long-run policy rates in the model are broadly in line with the official views of the central banks. The median of the longer-run FOMC summary of economic projections Federal Funds Rate has declined from 4% in 2013, to 3% in 2017 and in 2019 it has fallen to 2.5%.

[5] Estimating the excess wage growth parameter yields an estimated value in line with the calibrated value. Estimating the model without the excess parameter yields strongly downward trending foreign real marginal costs which is difficult to reconcile with largely stationary foreign CPI inflation. Smets and Wouters (2003) also incorporated an excess trend for euro area wages in their DSGE model already almost 20 years ago.

increased slightly in the sample period and even though wage growth in Sweden has been weak in the past decade we have decided not to incorporate a corresponding excess trend for Swedish wages. This choice implies that the resulting model measure (i.e. the smoothed estimate) of domestic real marginal cost is approximately stationary. The calibrations of steady-state inflation and wage inflation are both above their respective sample averages but these discrepancies largely cancel to produce an approximately stationary model measure of marginal cost. The steady states for productivity growth and the real wage are both closer to their respective sample averages. The smoothed estimates of the foreign and domestic real marginal cost series are displayed below.

Swedish trade with other countries as a share of GDP has increased in the sample period, arguably violating the assumption of balanced growth. Further, the trade shares increased at a faster rate in the pre-financial crisis period up to 2008. We therefore assume a common piecewise linear trend in the export and import shares through a time-varying parameter in the observation equations for exports and imports:

$$c_t^{\Delta X} = c_t^{\Delta M} = 3\%,\ t = 1995{:}2\text{–}2008{:}2,$$
$$c_t^{\Delta X} = c_t^{\Delta M} = 1\%,\ t = 2008{:}3\text{–}2018{:}4.$$

This means that the difference between the steady-state growth rates for trade and GDP in the latter part of the sample is assumed to be 1%, which is broadly in line with the data.

Finally, the relative price of imported consumption goods excluding energy has been trending down, i.e. the sample mean of imported consumption goods inflation is lower than that of CPIF inflation. We incorporate an excess parameter to capture the difference between the sample averages of CPIF inflation and imported inflation (1.5 and -0.4 percent respectively) and calibrate it as $c^{m,cxe} = -2.0$ which implies that the steady-state imported consumption goods excluding energy inflation equals $\pi^{m,cxe,obs} = \pi^{obs} + c^{m,cxe} = 2.0 - 2.0 = 0.0\%$. While we do not use data on price changes for domestically produced consumption goods, an implication is that the steady-state rate of price increase of these goods has to be larger than 2%. Again, note that our measure of import inflation is strongly correlated with the goods component of the CPI ('CPI goods'), which also means that the implied domestic component of inflation is rather strongly correlated with the services component in the CPI ('CPI services'). An alternative way of interpreting the import inflation excess parameter is then that it captures the declining price of goods relative to services in the sample period.

In summary, our assumptions concerning excess trends in the model are captured by the parameters c^{R^*} and c^R (interest rates), μ_Ψ (Swedish investment growth), $c^{\Delta Y}$ (Swedish GDP growth), $c_t^{\Delta X} = c_t^{\Delta M}$ (exports and imports), $c^{\Delta w^*}$ (foreign wage) and $c^{m,cxe}$ (import inflation). The steady-state values for all the observed variables are reported in the working paper such that they can be compared to the corresponding sample means (and also in Table 7 in the Appendix). All these parameters are calibrated in the baseline version of the model. In the model development phase, we have assessed the calibrations by estimating the excess trend parameters to ensure that the estimates do not significantly differ from the calibrated values presented above. Exceptions are the policy rate excess trend parameters, for the reasons discussed above.

2.2 Observation equations

The observation equation in vector form was provided above. The individual observation equations, i.e. the equations for each observed variable in the model, are listed in Table 8. The observation equations show how the data series are related to the variables in the DSGE model. The vector of 25 observed variables is given by

$$Y_t = \left(\left(Y_t^{for}\right)^T \ \left(Y_t^{dom}\right)^T \right)^T$$

where the 10 foreign observables are collected in the vector

$$\begin{aligned} Y_t^{for} = (& \Delta C_t^{*,obs} \quad \pi_t^{*,c,obs} \quad \pi_t^{*,cxe,obs} \quad N_t^{*,obs,gap} \quad \Delta Y_t^{*,obs} \\ & \Delta I_t^{*,obs} \quad R_t^{*,obs} \quad SPR_t^{*,obs} \quad U_t^{*,obs} \quad \Delta W_t^{*,obs} \ )^T, \end{aligned}$$

and where the 15 domestic observables are collected in the vector

$$Y_t^{dom} = (\; CU_t \quad \Delta C_t^{obs} \quad \pi_t^{c,obs} \quad \pi_t^{cxe,obs} \quad \pi_t^{m,cxe,obs} \quad N_t^{obs,gap} \quad \Delta X_t^{obs} \quad \Delta Y_t^{obs} \quad \Delta M_t^{obs} \quad \Delta I_t^{obs} \quad \Delta Q_t^{obs} \quad R_t^{obs} \quad SPR_t^{obs} \quad U_t^{obs} \quad \Delta W_t^{obs} \;)^T.$$

The observation error for a variable i, $\sigma_i^{me}\varepsilon_{i,t}^{me}$, is assumed to be independently normally distributed, where $\varepsilon_{i,t}^{me} \sim N(0,1)$ (independence across time and between variables). The standard deviation σ_i^{me} is generally calibrated such that the standard deviation of the observation error equals 10% of the sample standard deviation of the corresponding data series, i.e. $\sigma_i^{me} = 0.1 s_i$, where s_i is the sample standard deviation. The exceptions are the foreign and domestic policy rates, corporate spreads, unemployment rates and employment gaps. For these variables we instead assume $\sigma_i^{me} = 0$. The interest rates, and hence also the spreads, are assumed to be measured without error. For the labour market variables we choose to calibrate $\sigma_i^{me} = 0$ to avoid that a large share of e.g. the forecast error variance (at shorter forecast horizons) is being attributed to these errors. Essentially our assumptions on the observation errors imply that they do not account for a large fraction of the variation in any of the observed variables.

3 Estimation

3.1 Baseline model estimated using standard Bayesian method

3.1.1 Contemporaneous correlations in the model and the data

The joint posterior distribution of the foreign and domestic parameters in the model obtained by estimating it using Bayesian methods is reported in the working paper. In the working paper, we also compare the model-implied sample correlations with their counterparts in the data to asses how well the model fits the data. Here we provide additional material on the model's ability to fit the correlations in the data. In Figure 3 the data sample correlations (x-axis) are plotted against the posterior median of the model-implied sample correlations (y-axis). The model-implied posterior median sample correlations are computed based on the posterior distribution of the parameters. For each parameter draw from a thinned chain representing the posterior distribution an artificial dataset of length $T = 95$ is simulated and the sample correlations for the artificial dataset are computed. This yields a posterior distribution for the model-implied bivariate sample correlations. The top left graph in Figure 3 contains the bivariate correlations of all 300 pairs of variables in the model, the top right graph all foreign variable pairs (45 pairs), the bottom left graph all domestic variable pairs (105 pairs), and the bottom right graph all cross-country pairs (150 pairs). If the model perfectly reproduced the contemporaneous correlations in the data the points would be located on the 45 degree line displayed in the figures. First, these graphs illustrate that the model generally underestimates large correlations in the data (that is, large in absolute value). Second, it is not obvious visually from these graphs that the ability to capture cross-country correlations is much worse than the ability to capture within-country correlations.

In Table 9 the posterior distributions of the *population/theoretical* correlation between selected pairs of variables are provided and contrasted with the data sample correlation. The selected pairs are the same as those shown in the working paper in the case of model *sample* correlations. We note that the posterior probability intervals for the population correlations are narrower than those for the sample correlation based on simulated data from the model, where the latter are reported in the working paper. The former statistic takes into account uncertainty about the parameters, while the latter incorporates uncertainty about both the parameters and uncertainty stemming from the shocks. A discussion of the model's ability to fit the correlations in the data is provided in the working paper.

Table 8: Observation equations for the 25 observed variables used in estimation of the DSGE model.

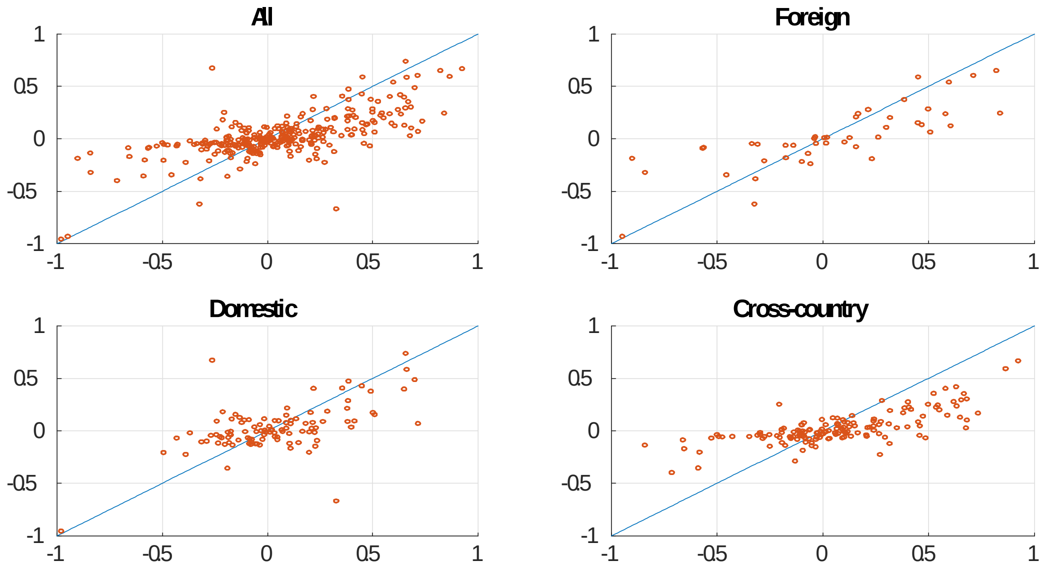
Variable	Equation
Foreign (KIX20)	
Cons.	$\Delta C_t^{*,obs} = c^{\Delta Y^*} + 400\ln(\mu_{z^+,*}) + 400\left(\hat{c}_t^* - \hat{c}_{t-1}^* + \hat{\mu}_{z^+,t}^*\right) + \sigma_{\Delta C^*}^{me}\varepsilon_{\Delta C^*,t}^{me}$
CPI	$\pi_t^{*,c,obs} = 400\ln(\pi^{c,*}) + 400\hat{\pi}_t^{c,*} + \sigma_{\pi^{c,*}}^{me}\varepsilon_{\pi^{c,*},t}^{me}$
CPI excl. en.	$\pi_t^{*,cxe,obs} = c^{cxe,*} + 400\ln(\pi^{c,*}) + 400\hat{\pi}_t^{cxe,*} + \sigma_{\pi^{cxe,*}}^{me}\varepsilon_{\pi^{cxe,*},t}^{me}$
Empl.	$N_t^{*,gap,obs} = 100\hat{N}_t^* + \sigma_{N^*}^{me}\varepsilon_{N^*,t}^{me}$
GDP	$\Delta Y_t^{*,obs} = c^{\Delta Y^*} + 400\ln(\mu_{z^+,*}) + 400\left(\hat{y}_t^* - \hat{y}_{t-1}^* + \hat{\mu}_{z^+,t}^*\right) + \sigma_{\Delta Y^*}^{me}\varepsilon_{\Delta Y^*,t}^{me}$
Invest.	$\Delta I_t^{*,obs} = c^{\Delta Y^*} + 400\ln(\mu_{z^+,*}) + 400\ln(\mu_{\Psi^*}) + 400\left(\widehat{i}_t^* - \widehat{i}_{t-1}^* + \hat{\mu}_{z^+,t}^* + \hat{\mu}_{\Psi,t}^*\right) + \sigma_{\Delta I^*}^{me}\varepsilon_{\Delta I^*,t}^{me}$
Policy rate	$R_t^{*,obs} = c^{R^*} + 400\ln\left(\mu_{z^+}^*\right) + 400\ln(\pi^*) - 400\ln\left(\beta^*\right) + 400\hat{R}_t^{*,dev,ss} + \sigma_{R^*}^{me}\varepsilon_{R^*,t}^{me}$
Corp. spread	$SPR_t^{*,obs} = SPR^{*,ss} + 400\chi_t^* + \sigma_{SPR^*}^{me}\varepsilon_{SPR^*,t}^{me}$
Unempl. rate	$U_t^{*,obs} = U^* + 100\hat{U}_t^* + \sigma_{U^*}^{me}\varepsilon_{U^*,t}^{me}$
Wage	$\Delta W_t^{*,obs} = c^{\Delta Y^*} + c^{\Delta w^*} + 400\ln(\pi^{c,*}) + 400\ln(\mu_{z^+}^*) + 400\hat{\pi}_t^{w,*} + \sigma_{\Delta W^*}^{me}\varepsilon_{\Delta W^*,t}^{me}$
Sweden	
Cap. util.	$CU_t = CU^{ss} + CU^{ss}\hat{u}_t + \sigma_{CU}^{me}\varepsilon_{CU,t}^{me}$
Cons.	$\Delta C_t^{obs} = c^{\Delta Y} + 400\ln(\mu_{z^+}) + 400\left(\hat{c}_t - \hat{c}_{t-1} + \hat{\mu}_{z^+,t}\right) + \sigma_{\Delta C}^{me}\varepsilon_{\Delta C,t}^{me}$
CPIF	$\pi_t^{c,obs} = 400\ln(\pi^c) + 400\hat{\pi}_t^c + \sigma_{\pi^c}^{me}\varepsilon_{\pi^c,t}^{me}$
CPIF ex. en	$\pi_t^{cxe,obs} = c^{cxe} + 400\ln(\pi^c) + 400\hat{\pi}_t^{cxe} + \sigma_{\pi^{cxe}}^{me}\varepsilon_{\pi^{cxe},t}^{me}$
CPIF imp. ex. en	$\pi_t^{m,cxe,obs} = c^{mcxe} + 400\ln(\pi^c) + 400\hat{\pi}_t^{m,c} + \sigma_{\pi^{m,cxe}}^{me}\varepsilon_{\pi^{m,cxe},t}^{me}$
Employment	$N_t^{obs,gap} = 100\hat{N}_t + \sigma_N^{me}\varepsilon_{N,t}^{me}$
Exports	$\Delta X_t^{obs} = c_t^{\Delta X} + c^{\Delta Y} + 400\ln(\mu_{z^+}) + 400\left(\hat{x}_t - \hat{x}_{t-1} + \hat{\mu}_{z^+,t}\right) + \sigma_{\Delta X}^{me}\varepsilon_{\Delta X,t}^{me}$
GDP	$\Delta Y_t^{obs} = c^{\Delta Y} + 400\ln(\mu_{z^+}) + 400\left(\hat{y}_t - \hat{y}_{t-1} + \hat{\mu}_{z^+,t}\right) + \sigma_{\Delta Y}^{me}\varepsilon_{\Delta Y,t}^{me}$
Imports	$\Delta M_t^{obs} = c_t^{\Delta M} + c^{\Delta Y} + 400\ln(\mu_{z^+}) + 400\left(\hat{m}_t - \hat{m}_{t-1} + \hat{\mu}_{z^+,t}\right) + \sigma_{\Delta M}^{me}\varepsilon_{\Delta M,t}^{me}$
Investment	$\Delta I_t^{obs} = c^{\Delta Y} + 400\ln(\mu_{z^+}) + 400\ln(\mu_\Psi) + 400\left(\widehat{i}_t - \widehat{i}_{t-1} + \hat{\mu}_{z^+,t} + \hat{\mu}_{\Psi,t}\right) + \sigma_{\Delta I}^{me}\varepsilon_{\Delta I,t}^{me}$
Real exch. rate	$\Delta Q_t^{obs} = 400\left(\hat{q}_t - \hat{q}_{t-1}\right) + \sigma_{\Delta Q}^{me}\varepsilon_{\Delta Q,t}^{me}$
Policy rate	$R_t^{obs} = c^R + 400\ln\left(\mu_{z^+}\right) + 400\ln(\pi) - 400\ln\left(\beta\right) + 400\hat{R}_t^{dev,ss} + \sigma_R^{me}\varepsilon_{R,t}^{me}$
Corp. spread	$SPR_t^{obs} = SPR^{ss} + 400\chi_t + \sigma_{SPR}^{me}\varepsilon_{SPR,t}^{me}$
Unempl. rate	$U_t^{obs} = U + 100\hat{U}_t + \sigma_U^{me}\varepsilon_{U,t}^{me}$
Wage	$\Delta W_t^{obs} = c^{\Delta Y} + 400\ln(\pi^c) + 400\ln(\mu_{z^+}) + 400\hat{\pi}_t^w + \sigma_{\Delta W}^{me}\varepsilon_{\Delta W,t}^{me}$

Table 9: Posterior distributions of contemporaneous model population/theoretical correlations. Selected pairs of foreign and/or Swedish variables.

Variable 1	Variable 2	Data	Posterior distribution percentile				
			5	12.5	50	87.5	95
Foreign (KIX20)	Sweden						
Policy rate	Policy rate	0.92	0.73	0.76	0.85	0.93	0.95
Corporate spread	Corporate spread	0.86	0.49	0.54	0.66	0.75	0.78
GDP	GDP	0.68	0.26	0.27	0.31	0.35	0.36
Unemployment rate	Unemployment rate	0.67	0.29	0.32	0.37	0.43	0.46
Employment	Employment	0.63	0.33	0.36	0.41	0.47	0.50
GDP	Imports	0.66	0.24	0.26	0.30	0.34	0.35
GDP	Exports	0.62	0.22	0.24	0.28	0.33	0.35
Consumption	Consumption	0.52	0.25	0.28	0.37	0.45	0.49
Investment	Investment	0.47	0.05	0.07	0.13	0.21	0.25
CPI	CPIF	0.40	0.22	0.23	0.26	0.30	0.31
Foreign (KIX20)	Foreign (KIX20)						
GDP	Investment	0.82	0.58	0.60	0.65	0.69	0.71
GDP	Consumption	0.71	0.53	0.56	0.62	0.67	0.69
CPIxe	Policy rate	0.58	0.07	0.09	0.15	0.21	0.24
CPI	Wage	0.51	0.00	0.02	0.08	0.16	0.20
Employment	Wage	0.50	0.20	0.23	0.29	0.36	0.40
Sweden	Sweden						
Wage	Policy rate	0.71	0.02	0.03	0.07	0.12	0.15
Exports	Imports	0.70	0.43	0.45	0.48	0.52	0.54
GDP	Exports	0.65	0.35	0.37	0.40	0.43	0.45
GDP	Investment	0.49	0.33	0.35	0.38	0.41	0.43
GDP	Real exchange rate	-0.39	-0.30	-0.27	-0.22	-0.17	-0.15

Note: Based on 5,000 thinned parameter draws from the joint posterior distribution (every 200th draw from a chain of length 1,000,000). For each parameter draw the population/theoretical correlation is computed. In the table, the distribution of model population/theoretical correlation is characterised through percentiles.

Figure 3: Scatter plots of contemporaneous sample correlations in the data (x-axis) and posterior median model sample correlations (y-axis). All variable pairs (top left), foreign pairs (top right), domestic pairs (bottom left) and foreign-domestic pairs (bottom right).



3.2 Baseline model estimated using the marginal-conditional Bayesian approach

3.2.1 Conditional posterior mode of domestic economy parameters

The marginal posterior distribution for the foreign parameters is reported in the working paper. As discussed there the marginal and joint posterior estimates of the 37 estimated foreign economy parameters are generally very similar. The conditional posterior distribution of the 54 estimated domestic economy parameters is obtained by estimating the domestic parameters using foreign and domestic data while conditioning on the foreign economy marginal posterior mode parameter estimates. The conditional posterior mode estimates of the domestic parameters are reported in Table 10. The posterior mode estimates from Bayesian estimation of the joint (foreign and domestic economy parameters) posterior distribution are included for comparison (within parentheses). The median difference between the conditional and joint posterior mode estimates of the domestic economy parameters equals 1.3 percent, which means that the parameter estimates are generally very similar.[6] A comparison of the marginal-conditional and joint posterior estimation approaches suggests that the overall differences in both the foreign and domestic parameter estimates obtained are small. The main takeaway from the marginal-conditional estimation is that the inclusion of Swedish data series when the foreign and domestic economy parameters are estimated jointly does not significantly affect the foreign parameter estimates. We note that while this result holds in the case of our model it may not hold more generally for two-region (block-exogenous) DSGE models.

3.3 Baseline model estimated using the modified posterior

3.3.1 Modified posterior distribution: matched moments

The modified posterior

$$\frac{p\left(\theta_{est}|y_{1:T}\right)}{f((S_m - S_d)^2\,|\theta_{est};y_{1:T})} \tag{3.1}$$

[6]Since the conditional and joint posterior mode estimates of the domestic parameters are very similar we do not report the conditional posterior distribution.

Table 10: Conditional posterior mode estimates of domestic parameters. Joint posterior mode estimates in parentheses. (Foreign economy parameters calibrated to their marginal posterior mode estimates in conditional estimation. Foreign and domestic data series used in estimation.)

Parameter		Post. mode	Parameter		Post. mode
b	Habit	0.75 (0.75)	σ_{ϵ}	Temp. techn.	0.59 (0.59)
ξ_d	Calvo, dom. price	0.94 (0.94)	$\sigma_{p^{d,ce}}$	Energy, relative price	0.51 (0.51)
$\xi_{m,c}$	Calvo,imp. cons.	0.92 (0.92)	σ_{ε_R}	Monetary policy	0.06 (0.05)
$\xi_{m,i}$	Calvo, imp. inv.	0.78 (0.79)	σ_g	Gov. cons.	0.26 (0.26)
$\xi_{m,x}$	Calvo, imp. exp.	0.80 (0.80)	σ_{χ}	Risk premium	0.04 (0.04)
ξ_x	Calvo, exp.	0.79 (0.79)	σ_{λ^d}	Markup, dom.	0.07 (0.07)
ξ_w	Calvo,wage	0.86 (0.86)	$\sigma_{\lambda^{m,c}}$	Markup, imp. cons.	0.07 (0.07)
η_c	Subst., dom and imp, cons	0.85 (0.87)	$\sigma_{\lambda^{m,i}}$	Markup, imp. inv.	0.88 (0.91)
η_i	Subst., dom and imp, inv	0.27 (0.27)	$\sigma_{\lambda^{m,x}}$	Markup, imp. exp.	0.10 (0.10)
η_f	Subst.,dom and imp goods	0.38 (0.37)	σ_{λ^x}	Markup, exp.	0.11 (0.11)
η_x	Subst., dom. and imp. exp.	1.51 (1.53)	$\sigma_{\tilde{\phi}}$	UIP,risk premium	0.30 (0.30)
$\tilde{\phi}_s$	UIP, risk premium	0.16 (0.16)	σ_{Υ}	Temp. inv.	0.21 (0.22)
σ_a	Capital util.	0.17 (0.17)	σ_{ζ^c}	Cons. preference	0.21 (0.22)
$\tilde{S}''$	Inv. adj. cost	8.11 (8.39)	σ_{ζ^n}	Labour supply	0.11 (0.10)
φ	Labour disutility	3.96 (3.65)	σ_{λ^w}	Wage markup	0.10 (0.09)
ω_c^x	Exp., weight on for- cons.	0.30 (0.27)	$\sigma_{\bar{\pi}^c}$	Inflation trend	0.55 (0.50)
ρ_R	Smoothing	0.93 (0.92)	c_{ϵ,ϵ^*}	Temp. techn.	0.36 (0.41)
r_{π}	Inflation	1.74 (1.71)	$c_{p^{d,ce},p^{ce,*}}$	Energy, rel. price	0.33 (0.34)
r_{RU}	Unemp.rate	0.25 (0.25)	c_{g,g^*}	Gov. cons.	0.59 (0.59)
$r_{\Delta RU}$	Unemp.rate, change	0.18 (0.17)	c_{Υ,Υ^*}	Inv.	0.05 (0.07)
r_{χ}	Spread	0.61 (0.59)	$c_{\zeta^c,\zeta^{c,*}}$	Cons. pref.	0.31 (0.35)
ρ_{ϵ}	Temp. techn.	0.87 (0.87)	$c_{\zeta^n,\zeta^{n,*}}$	Labour supply	0.42 (0.44)
$\rho_{p^{d,ce}}$	Energy, rel. price	0.87 (0.88)	c_{χ,χ^*}	Risk premium	0.71 (0.68)
ρ_g	Gov. cons.	0.67 (0.66)	$c_{\tilde{\phi},\,-\mu_z^*}$	UIP risk premium	0.17 (0.16)
ρ_{χ}	Risk premium	0.69 (0.69)	$c_{\lambda^{m,i},\,-\mu_z^*}$	Markup, imp. inv.	0.31 (0.31)
ρ_{ζ^n}	Labour supply	0.87 (0.83)			
$\rho_{\tilde{\phi}}$	UIP risk premium	0.84 (0.84)			
ρ_{λ^w}	Wage markup	0.46 (0.44)			

Note: The conditional posterior mode for the vector of domestic economy parameters in the two-country model is obtained by optimising the conditional posterior density while the foreign parameters are calibrated at their marginal posterior mode estimates. Foreign and domestic data series are used in estimation.

adds the penalty term f to the posterior $p(\theta_{est}|y_{1:T})$. The penalty term penalizes large deviations between a set of model-implied second moments, S_m, and their sample counterparts, S_d. In optimising and sampling from the modified posterior, we are interested in the question of how the estimation method, by targeting a set of key moments (collected in S_m), can contribute to increase the spillovers from the foreign to the domestic economy. Intuitively the modified posterior attaches more weight to certain moments in the data, and in particular to the covariances of some pairs of Swedish and foreign variables which are strongly correlated in the data. In the working paper, it is shown that the share of the forecast error variance of domestic variables attributed to foreign shocks is larger when the variance decomposition is computed for the modified posterior mode parameter vector in comparison with the posterior mode parameter obtained using standard Bayesian estimation.

The penalty is a function of the deviation between a selected set of population (i.e. stationary distribution) second moments in the model (which can be computed using the Lyapunov equation; see the working paper) and the corresponding data sample moments. The method follows Christiano, Trabandt, and Walentin (2011) closely. A large sample approximation to the likelihood of the moments is constructed, what we refer to as the 'penalty' since large deviations between the moments in the model and the data are penalized.[7]

The variances of the following 16 variables are included in the vector of targeted moments; 6 foreign variables

$$\Delta C_t^{*,obs},\ \pi_t^{*,c,obs},\ \pi_t^{*,cxe,obs},\ \Delta Y_t^{*,obs},\ \Delta I_t^{*,obs},\ \Delta W_t^{*,obs},$$

and 10 domestic variables

$$\Delta C_t^{obs}, \Delta I_t^{obs}, \Delta M_t^{obs}, \Delta Q_t^{obs}, \Delta Y_t^{obs}, \Delta X_t^{obs}, \pi_t^{c,obs}, \pi_t^{cxe,obs}, \pi_t^{m,cxe,obs}, \Delta W_t^{obs}.$$

For these variables the unit root hypothesis is rejected at the 1% significance level with an ADF test; see the working paper. In addition we match the covariances of 20 pairs of observed variables (out of a total of $\frac{25*24}{2} = 300$ possible pairs since we have 25 observed variables) for a total of $16 + 20 = 36$ matched moments. The selection of the set of pairs for which the covariances are matched is obviously somewhat arbitrary. We have generally chosen pairs for which i) the correlation in the data sample is 'large' and/or ii) Sweden-foreign same variable pairs, e.g. Swedish and foreign GDP growth. The following 10 covariances for pairs of Swedish and foreign variables are matched

$$\left(\Delta Y_t^{*,obs}, \Delta Y_t^{obs}\right),\ \left(\Delta C_t^{*,obs}, \Delta C_t^{obs}\right),\ \left(\Delta I_t^{*,obs}, \Delta I_t^{obs}\right), \left(\Delta Y_t^{*,obs}, \Delta X_t^{obs}\right), \left(\Delta Y_t^{*,obs}, \Delta M_t^{obs}\right),$$
$$\left(R_t^{*,obs}, R_t^{obs}\right),\ \left(\pi_t^{*,c,obs}, \pi_t^{c,obs}\right),\ \left(\pi_t^{*,cxe,obs}, \pi_t^{cxe,obs}\right),\ \left(\Delta W_t^{*,obs}, \Delta W_t^{obs}\right),\ \left(U_t^{*,obs}, U_t^{obs}\right).$$

In addition we match the following 4 covariances among Swedish GDP and its components

$$\left(\Delta Y_t^{obs}, \Delta C_t^{obs}\right),\ \left(\Delta Y_t^{obs}, \Delta I_t^{obs}\right),\ \left(\Delta Y_t^{obs}, \Delta X_t^{obs}\right),\ \left(\Delta Y_t^{obs}, \Delta M_t^{obs}\right),$$

and an additional 6 covariances among the following pairs of foreign variables

$$\left(\Delta Y_t^{*,obs}, \Delta C_t^{*,obs}\right),\ \left(\Delta Y_t^{*,obs}, \Delta I_t^{*,obs}\right),\ \left(\Delta W_t^{*,obs}, \pi_t^{*,c,obs}\right),$$
$$\left(U_t^{*,obs}, \Delta W_t^{*,obs}\right),\ \left(\pi_t^{*,cxe,obs}, \Delta W_t^{*,obs}\right),\ \left(\pi_t^{*,cxe,obs}, U_t^{*,obs}\right).$$

3.3.2 Modified posterior distribution of parameters

The modified posterior distribution is presented in Table 11 (foreign parameters), Table 12 (domestic structural parameters) and Table 13 (domestic shock process parameters). The foreign and domestic parameters are estimated jointly. An overall comparison of the modified posterior mode with the posterior mode from the standard Bayesian estimation (which is shown within parenthesis in the tables)

[7] The estimation method is available in Dynare ('endogenous prior') and we have extended it to allow for matching of covariances in addition to variances.

suggests that both real and nominal rigidities and the shock correlation parameters are generally estimated larger with the modified posterior. In particular, the modified posterior estimates of the foreign and domestic Calvo parameters ξ^* and ξ_d are large and the modified posterior standard deviations of these parameters are small.

3.3.3 Model standard deviations and correlations: posterior vs. modified posterior modes

In Table 14 and Table 15, we compare model-implied population standard deviations and contemporaneous correlations computed at the posterior and modified posterior modes, respectively, and also compare these to the corresponding data sample quantities. Note again that it is the population/theoretical model statistics, rather than sample/simulated statistics, which are matched to the data sample statistics in the estimation procedure. Intuitively, the modified posterior will trade-off the posterior and the penalty. It is clear that we must have

$$f(\left(S_m\left(\hat{\theta}_{est}^{m,p}\right) - S_d\right)^2 |\hat{\theta}_{est}^{m,p}; y_{1:T}) < f(\left(S_m\left(\hat{\theta}_{est}^{p}\right) - S_d\right)^2 |\hat{\theta}_{est}^{p}; y_{1:T})$$

where $\hat{\theta}_{est}^{p}$ is the posterior mode and $\hat{\theta}_{est}^{m,p}$ is the modified posterior mode, i.e. the penalty function evaluated at the modified posterior mode must attain a smaller value than the penalty evaluated at the posterior mode. The moments considered in these tables are those targeted by the penalty function, i.e. the 16 variances and 20 covariances described above which are included in S_m, but we choose to report the comparison in terms of standard deviations rather than variances (which is inconsequential) and correlations instead of covariances (since the correlations are easier to interpret). The purpose of the comparison is, first, to assess how well the model can match these moments and, second, to assess the improvements in fit with the modified posterior mode estimate.

The main result from estimating the model using the modified posterior can be stated succinctly. The modified posterior estimate brings the properties of Swedish GDP growth closer to those in the data — its volatility and correlation with other variables in the model is brought more in line with the data.

The baseline model estimated using standard Bayesian methods obtains a very good fit in terms of the volatility of the observed variables. The mean deviation between the model population standard deviation and the data sample standard deviation is a mere 11%, and, hence, it should be difficult for the modified posterior to improve substantially on this. The largest deviation is obtained for Swedish GDP growth where the model substantially overestimates the volatility. The ability to match the standard deviations improves only very marginally with the modified posterior mode estimate. First, it is difficult to improve substantially on the posterior mode. Second, it could reflect that there is a trade-off between matching the variances and the covariances well (see below). However, the standard deviation of Swedish GDP growth is brought more in line with the data standard deviation.

The model population correlations computed at the posterior and modified posterior modes are reported in Table 15. The ability to match these correlations generally improves at the modified posterior mode, in comparison with the posterior mode, which is to be expected. The median deviation between the model population correlation and the data sample correlation is 0.22 for the posterior mode and somewhat lower, 0.16, for the modified posterior mode. It is primarily the ability to match correlations between Swedish GDP growth and other variables which improves with the modified posterior, which is seen in the top rows in the table.

3.3.4 Modified posterior distributions of observed variables standard deviations and sample correlations

In this section, we report modified posterior distributions of observed variables' sample standard deviations (Table 16), sample correlations (Table 17) and population correlations (Table 18). Posterior

Table 11: Modified posterior distribution of foreign economy parameters.

Parameter		Prior Dist	Mean	Std	Scale	Posterior Mode	Median	Std	5%	95%
b^*	Habit	B	0.75	0.10		0.67 (0.64)	0.69	0.04	0.63	0.75
ξ^*	Calvo, price	B	0.75	0.075		0.97 (0.92)	0.97	0.01	0.96	0.98
ξ^*_w	Calvo wage	B	0.75	0.075		0.89 (0.86)	0.90	0.01	0.88	0.92
φ^*	Labour disutility	G	3.0	1.5		6.61 (6.00)	7.23	1.23	5.59	9.58
$\tilde{S}'',^*$	Inv. adj.cost	N	5.0	2.5		1.74 (3.99)	1.46	0.12	1.27	1.69
κ^*	Indexation, price	B	0.5	0.2		0.25 (0.55)	0.26	0.08	0.13	0.39
	Monetary policy									
ρ_{R^*}	Smoothing	B	0.85	0.10		0.95 (0.93)	0.95	0.01	0.93	0.97
r_{π^*}	Inflation	N	1.75	0.15		1.75 (1.75)	1.76	0.15	1.52	2.00
r_{RU^*}	Unempl. rate	N	0.125	0.125		0.19 (0.12)	0.20	0.05	0.14	0.29
$r_{\Delta RU^*}$	Unem. rate, change	N	0.15	0.075		0.24 (0.24)	0.24	0.02	0.20	0.28
r_{χ^*}	Spread	N	0	1		0.60 (0.57)	0.60	0.14	0.36	0.82
	Shock persistence									
ρ_{ϵ^*}	Temp. technology	B	0.75	0.10		0.89 (0.81)	0.88	0.06	0.75	0.95
$\rho_{p^{ce,*}}$	Energy, rel. price	B	0.75	0.10		0.91 (0.91)	0.90	0.02	0.86	0.94
ρ_{g^*}	Gov. cons.	B	0.75	0.10		0.98 (0.98)	0.98	0.01	0.97	0.99
ρ_{χ^*}	Risk premium	B	0.75	0.10		0.91 (0.91)	0.91	0.02	0.87	0.95
$\rho_{\lambda^{w,*}}$	Wage markup	B	0.75	0.10		0.74 (0.90)	0.72	0.04	0.66	0.80
$\rho_{\mu^*_z}$	Perm. techn.	B	0.75	0.10		0.51 (0.55)	0.50	0.04	0.43	0.57
ρ_{Υ^*}	Temp. inv.	B	0.75	0.10		0.68 (0.66)	0.68	0.04	0.61	0.75
$\rho_{\zeta^{c,*}}$	Cons. pref.	B	0.75	0.10		0.63 (0.73)	0.58	0.05	0.49	0.66
$\rho_{\zeta^{n,*}}$	Labour supply	B	0.75	0.10		0.99 (0.99)	0.99	0.01	0.97	0.99
ρ_{z^*}	Real int. rate trend	B	0.85	0.10		0.99 (0.99)	0.98	0.004	0.98	0.99
	Shock, MA									
$\theta_{\lambda^{w,*}}$	Wage markup	N	0.0	0.5		0.75 (0.85)	0.75	0.12	0.64	0.84
θ_{z^*}	Real int. rate trend	N	0.0	0.5		-0.81 (-0.75)	-0.83	0.18	-1.15	-0.57
	Innovation std.									
σ_{ϵ^*}	Temp technology	IG	0.2	∞	0.01	0.08 (0.06)	0.08	0.02	0.06	0.12
$\sigma_{p^{ce,*}}$	Energy, rel price	IG	0.2	∞	0.10	0.29 (0.29)	0.29	0.02	0.26	0.31
$\sigma_{\varepsilon^*_R}$	Monetary policy	IG	0.1	∞	0.01	0.03 (0.03)	0.03	0.004	0.02	0.03
σ_{g^*}	Gov. cons.	IG	0.2	∞	0.1	0.09 (0.10)	0.10	0.01	0.08	0.09
σ_{χ^*}	Risk premium	IG	0.2	∞	0.001	0.33 (0.33)	0.33	0.03	0.29	0.38
σ_{λ^*}	Price markup	IG	0.2	∞	1	0.92 (0.18)	1.26	0.69	0.67	2.80
$\sigma_{\lambda^{w,*}}$	Wage markup	IG	0.2	∞	10	0.19 (0.10)	0.24	0.07	0.15	0.39
$\sigma_{\mu^*_z}$	Perm. techn.	IG	0.2	∞	0.01	0.37 (0.42)	0.37	0.03	0.33	0.41
σ_{Υ^*}	Temp inv.	IG	0.2	∞	0.1	0.14 (0.26)	0.13	0.01	0.11	0.15
$\sigma_{\zeta^{c,*}}$	Cons. pref.	IG	0.2	∞	0.1	0.06 (0.06)	0.07	0.01	0.06	0.09
$\sigma_{\zeta^{n,*}}$	Labour supply	IG	0.2	∞	0.1	0.10 (0.09)	0.11	0.02	0.09	0.15
σ_{z^*}	Real int. rate trend	IG	0.1	∞	0.01	0.04 (0.04)	0.04	0.01	0.03	0.05
$\sigma_{\bar{\pi}^{c,*}}$	Inflation trend	IG	0.1	∞	0.001	0.40 (0.05)	0.39	0.03	0.33	0.44
	Shock, correlation									
$c_{\zeta^{c,*},\Upsilon^*}$	Cons. pref., inv.	B	0.5	0.2		0.64 (0.59)	0.61	0.09	0.45	0.73

Note: Based on 1,000,000 draws from the joint modified posterior distribution of the two-region DSGE model. Foreign and domestic data series used in estimation. The marginal posterior mode from Bayesian estimation is reported in parentheses for comparison. The joint posterior mode of the foreign parameters is reported in the working paper and it is very similar to the marginal posterior mode.

Table 12: Modified posterior distribution: domestic economy structural parameters.

Parameter		Prior Dist	Mean	Std	Posterior Mode	Median	Std	5%	95%
b	Habit	B	0.75	0.10	0.79 (0.75)	0.80	0.03	0.75	0.84
ξ_d	Calvo, dom. price	B	0.75	0.075	0.95 (0.94)	0.96	0.01	0.95	0.96
$\xi_{m,c}$	Calvo,imp. cons.	B	0.75	0.075	0.93 (0.92)	0.93	0.01	0.92	0.95
$\xi_{m,i}$	Calvo, imp. inv.	B	0.75	0.075	0.74 (0.79)	0.74	0.03	0.69	0.79
$\xi_{m,x}$	Calvo, imp. exp.	B	0.75	0.075	0.84 (0.80)	0.85	0.02	0.81	0.88
ξ_x	Calvo, exp.	B	0.75	0.075	0.82 (0.79)	0.84	0.02	0.81	0.88
ξ_w	Calvo,wage	B	0.75	0.075	0.84 (0.86)	0.84	0.02	0.82	0.87
η_c	Subst., dom and imp, cons	G	1.01	0.5	0.77 (0.87)	0.86	0.39	0.36	1.86
η_i	Subst., dom and imp, inv	G	1.01	0.5	0.49 (0.27)	0.49	0.08	0.36	0.63
η_f	Subst.,dom and imp goods	G	1.01	0.5	0.55 (0.37)	0.51	0.27	0.20	1.04
η_x	Subst., dom. and imp, exp.	G	1.01	0.5	1.91 (1.53)	2.09	0.54	1.38	3.21
$\tilde{\phi}_s$	UIP, risk premium	B	0.5	0.2	0.22 (0.16)	0.25	0.05	0.18	0.34
σ_a	Capital util.	IG	0.5	∞	0.73 (0.17)	0.73	0.17	0.50	1.06
$\tilde{S}''$	Inv. adj. cost	N	5.0	2.5	11.17 (8.39)	11.59	1.20	9.71	13.67
φ	Labour disutility	G	3.0	1.5	4.61 (3.65)	4.92	0.96	3.62	6.85
ω_c^x	Exp., weight on for cons.	B	0.5	0.2	0.13 (0.27)	0.15	0.07	0.05	0.28
	Monetary policy								
ρ_R	Smoothing	B	0.85	0.10	0.92 (0.92)	0.92	0.02	0.89	0.94
r_π	Inflation	N	1.75	0.15	1.73 (1.71)	1.71	0.15	1.46	1.97
r_{RU}	Unempl. rate	N	0.125	0.125	0.22 (0.25)	0.23	0.06	0.15	0.33
$r_{\Delta RU}$	Unempl. rate, change	N	0.15	0.075	0.16 (0.17)	0.16	0.02	0.12	0.20
r_χ	Spread	N	0	1	0.65 (0.59)	0.67	0.16	0.39	0.93

Note: Based on 1,000,000 draws from the joint modified posterior distribution for the vector of foreign and domestic economy parameters in the two-region DSGE model. Foreign and domestic data series used in estimation. The posterior mode from standard Bayesian estimation is reported in parenthesis for comparison.

Table 13: Modified posterior distribution: domestic economy shock process parameters.

Parameter		Prior Dist	Mean	Std	Scale	Posterior Mode	Median	Std	5%	95%
	Shock persistence									
ρ_{ϵ}	Temp. techn.	B	0.5	0.2		0.87 (0.87)	0.87	0.05	0.77	0.92
$\rho_{p^{d,ce}}$	Energy, rel. price	B	0.5	0.2		0.78 (0.88)	0.78	0.09	0.62	0.90
ρ_{g}	Gov. cons.	B	0.5	0.2		0.65 (0.66)	0.65	0.10	0.48	0.79
ρ_{χ}	Risk premium	B	0.5	0.2		0.70 (0.69)	0.70	0.05	0.61	0.79
$\rho_{\zeta^{n}}$	Labour supply	B	0.5	0.2		0.79 (0.83)	0.79	0.08	0.65	0.89
$\rho_{\tilde{\phi}}$	UIP risk premium	B	0.5	0.2		0.84 (0.84)	0.79	0.08	0.63	0.87
$\rho_{\lambda^{w}}$	Wage markup	B	0.5	0.2		0.59 (0.44)	0.59	0.07	0.46	0.68
	Innovation standard deviation									
σ_{ϵ}	Temp. techn.	IG	0.2	∞	0.01	0.59 (0.59)	0.60	0.05	0.53	0.68
$\sigma_{p^{d,ce}}$	Energy, relative price	IG	0.2	∞	0.10	0.52 (0.51)	0.52	0.03	0.47	0.57
$\sigma_{\varepsilon_{R}}$	Monetary policy	IG	0.2	∞	0.01	0.06 (0.05)	0.06	0.01	0.05	0.07
σ_{g}	Gov. cons.	IG	0.2	∞	0.1	0.14 (0.26)	0.14	0.01	0.13	0.15
σ_{χ}	Risk premium	IG	0.2	∞	0.01	0.04 (0.04)	0.04	0.003	0.03	0.04
$\sigma_{\lambda^{d}}$	Markup, dom.	IG	0.2	∞	10	0.09 (0.07)	0.10	0.03	0.07	0.15
$\sigma_{\lambda^{m,c}}$	Markup, imp. cons.	IG	0.2	∞	10	0.08 (0.07)	0.08	0.02	0.05	0.13
$\sigma_{\lambda^{m,i}}$	Markup, imp. inv.	IG	0.2	∞	1	0.82 (0.91)	0.88	0.18	0.63	1.24
$\sigma_{\lambda^{m,x}}$	Markup, imp. exp.	IG	0.2	∞	10	0.08 (0.10)	0.08	0.02	0.05	0.12
$\sigma_{\lambda^{x}}$	Markup, exp.	IG	0.2	∞	10	0.09 (0.11)	0.11	0.03	0.09	0.18
$\sigma_{\tilde{\phi}}$	UIP,risk premium	IG	0.2	∞	0.01	0.28 (0.30)	0.33	0.11	0.23	0.51
σ_{Υ}	Temp. inv.	IG	0.2	∞	1	0.24 (0.22)	0.25	0.03	0.21	0.30
$\sigma_{\zeta^{c}}$	Cons. preference	IG	0.2	∞	0.1	0.22 (0.22)	0.24	0.04	0.19	0.30
$\sigma_{\zeta^{n}}$	Labour supply	IG	0.2	∞	0.1	0.12 (0.10)	0.13	0.03	0.10	0.19
$\sigma_{\lambda^{w}}$	Wage markup	IG	0.2	∞	10	0.07 (0.09)	0.07	0.01	0.05	0.10
$\sigma_{\bar{\pi}^{c}}$	Inflation trend	IG	0.2	∞	0.001	0.28 (0.50)	0.27	0.09	0.13	0.42
	Shock correlations									
$c_{\epsilon,\epsilon^{*}}$	Temp. techn.	B	0.5	0.2		0.49 (0.41)	0.47	0.15	0.21	0.72
$c_{p^{d,ce},p^{ce,*}}$	Energy, rel. price	B	0.5	0.2		0.57 (0.34)	0.53	0.13	0.29	0.71
$c_{g,g^{*}}$	Gov. cons.	B	0.5	0.2		0.81 (0.59)	0.76	0.12	0.50	0.89
$c_{\Upsilon,\Upsilon^{*}}$	Inv.	B	0.5	0.2		0.10 (0.07)	0.10	0.03	0.06	0.15
$c_{\zeta^{c},\zeta^{c,*}}$	Cons. pref.	B	0.5	0.2		0.45 (0.35)	0.45	0.06	0.35	0.54
$c_{\zeta^{n},\zeta^{n,*}}$	Labour supply	B	0.5	0.2		0.44 (0.44)	0.42	0.16	0.17	0.68
$c_{\chi,\chi^{*}}$	Risk premium	B	0.5	0.2		0.69 (0.68)	0.66	0.10	0.48	0.80
$c_{\tilde{\phi},\,-\mu_{z}^{*}}$	UIP risk premium	B	0.5	0.2		0.20 (0.16)	0.21	0.06	0.13	0.32
$c_{\lambda^{m,i},\,-\mu_{z}^{*}}$	Markup, imp. inv.	B	0.5	0.2		0.36 (0.31)	0.36	0.05	0.28	0.45

Note: Based on 1,000,000 draws from the joint modified posterior distribution for the vector of foreign and domestic economy parameters in the two-region DSGE model. Foreign and domestic data series used in estimation. The posterior mode from standard Bayesian estimation is reported in parenthesis for comparison.

Table 14: Model population standard deviations for a subset of the observed variables. Computed at the posterior and modified posterior modes. Comparison with data sample standard deviations.

Variable	Data	Post. mode	Mod. post mode
Foreign (KIX20)			
GDP	2.1	1.8	1.6
Consumption	1.4	1.5	1.4
Investment	5.2	5.1	4.9
CPI	1.3	1.3	1.2
Wage	0.9	1.0	0.8
CPIxe	0.7	0.7	0.6
Sweden			
GDP	3.6	5.7	3.9
Consumption	2.8	2.7	2.5
Investment	10.6	11.2	10.0
Exports	9.6	8.9	8.2
Imports	9.1	8.7	7.7
CPIF	1.2	1.5	1.3
Wage	1.1	1.2	1.5
CPIFxe	0.9	1.1	0.9
CPIF imp., excl. en.	1.9	1.9	1.7
Real exch. rate	9.8	9.7	9.6
Mean deviation, %		11%	10%

distributions for these statistics are presented in the working paper. The overall impression of the modified posterior distributions of the observed variables' standard deviations is that the standard deviations are estimated lower with the modified posterior in comparison with the posterior. The ability of the modified posterior probability intervals to cover the corresponding data standard deviation does not appear to be better than for the posterior. Instead, for most variables the modified posterior coverage probability is larger than the corresponding posterior probability (see the working paper). An important exception is, again, Swedish GDP growth for which the modified posterior improves on the posterior.

The correlations between selected pairs of variables, on the other hand, appear to be better captured by the modified posterior. In Tables 17 and 18, we include a qualitative assessment to indicate whether the modified posterior probability interval for the correlation better captures the data sample correlation, in comparison with the corresponding posterior interval. 'Improve' means that the modified posterior captures the correlation in a better way, while 'worse' means that the posterior interval 'looks better'.

In summary, the modified posterior distribution captures some of the strong correlations in the data better than the posterior distribution. Surprisingly, however, the ability of the modified posterior to match the volatilities of the observed variables does not appear to be better judged by the coverage probabilities reported above.

4 Forecast error variance decompositions

In Table 19 (foreign variables) and Table 20 (domestic variables) forecast error variance decompositions (FEVD) at forecast horizon 8 quarters are reported for a set of variables. The variables are the foreign and Swedish annual GDP per capita growth rate ($\Delta Y_t^{*,a}$, ΔY_t^{a}), the unemployment rate (U_t^*,

Table 15: Model population correlations for the 20 pairs of observed variables matched in modified posterior estimation. Correlations computed at posterior and modified posterior mode parameters. Comparison with data sample correlations.

Variable 1	Variable 2	Data	Post.	Mod. post
GDP	Cons.	0.50	0.17	0.30
GDP	Invest.	0.49	0.37	0.47
GDP	Exports	0.65	0.40	0.54
GDP	Imports	0.51	0.16	0.35
GDP	For GDP	0.68	0.31	0.44
Cons	For cons.	0.52	0.34	0.46
Invest.	For invest.	0.47	0.12	0.14
Exports	For GDP	0.62	0.29	0.34
Imports	For GDP	0.66	0.30	0.41
CPIF	For CPI	0.40	0.27	0.31
Repo rate	For pol. rate	0.92	0.89	0.86
Unempl.	For unempl.	0.67	0.39	0.44
Wage	For wage	0.27	0.14	0.10
CPIFxe	For CPIxe	0.07	0.13	0.09
For GDP	For cons.	0.71	0.62	0.62
For GDP	For invest.	0.82	0.66	0.67
For CPI	For wage	0.51	0.06	0.16
For wage	For unempl.	-0.46	-0.41	-0.35
For wage	For CPIxe	0.47	0.12	0.33
For unempl	For CPIxe	-0.32	-0.36	-0.26
Mean abs. deviation			0.22	0.16

Table 16: Modified posterior distribution of observed variables' standard deviations.

Variable	Transf. and unit	Data	Posterior distribution Percentile 5	12.5	50	87.5	95	Cover
Foreign (KIX20)								
Consumption	Per cap, 4qq, perc	1.45	1.11	1.17	1.32	1.48	1.56	75
CPI	4qq, perc	1.33	1.05	1.10	1.21	1.33	1.39	75
CPI excluding energy	4qq, perc	0.67	0.46	0.49	0.57	0.67	0.74	75
Employment	Per cap, perc	1.91	0.73	0.83	1.09	1.44	1.63	Outside 95
GDP	Per cap, 4qq, perc	2.13	1.35	1.42	1.59	1.78	1.86	Outside 95
Investment	Per cap, 4qq, perc	5.23	4.15	4.37	4.89	5.47	5.73	75
Policy rate	Perc	2.01	0.77	0.88	1.21	1.69	1.94	95
Corporate spread	Perc points	0.46	0.19	0.22	0.28	0.38	0.43	Outside 95
Unemployment rate	Perc	1.22	0.61	0.69	0.90	1.17	1.31	90
Wage	4qq, perc	0.87	0.62	0.65	0.74	0.85	0.92	90
Sweden								
Capacity utilization	Perc	3.36	2.08	2.29	2.92	3.75	4.18	50
Consumption	Per cap, 4qq, perc	2.76	2.11	2.21	2.45	2.70	2.83	90
CPIF	4qq, perc	1.20	1.14	1.19	1.31	1.45	1.50	75
CPIF excl. energy	4qq, perc	0.92	0.73	0.76	0.85	0.95	1.00	75
CPIF imp. excl. energy	4qq, perc	1.90	1.44	1.51	1.67	1.84	1.93	90
Employment	Per cap, perc	1.95	1.45	1.57	1.89	2.29	2.48	50
Exports	Per cap, 4qq, perc	9.56	7.06	7.35	8.08	8.86	9.21	Outside 95
GDP	Per cap, 4qq, perc	3.64	3.43	3.56	3.90	4.24	4.40	75
Imports	Per cap, 4qq, perc	9.13	6.70	6.99	7.70	8.46	8.79	Outside 95
Investment	Per cap, 4qq, perc	10.61	8.54	8.92	9.92	11.07	11.55	50
Real exchange rate	4qq, perc	9.81	8.29	8.70	9.63	10.61	11.07	50
Policy rate	Perc	2.19	1.02	1.13	1.47	1.92	2.16	95
Corporate spread	Perc points	0.40	0.21	0.22	0.28	0.36	0.40	90
Unemployment rate	Perc	1.41	1.25	1.35	1.62	1.96	2.13	90
Wage	4qq, perc	1.14	1.17	1.24	1.42	1.63	1.74	Outside 95

Based on 5,000 thinned parameter draws from the joint modified posterior distribution (every 200th draw from a chain of length 1,000,000). For each parameter draw an artificial data sample of size T=95 is simulated using the model and the sample standard deviation is computed. In the table, the distribution of model sample standard deviations is characterised through percentiles. 'Cover' indicates the mass of the smallest probability interval which includes the corresponding data sample standard deviation, selected among 50, 75, 90 and 95 percent intervals.

Table 17: Modified posterior distribution of contemporaneous sample correlations, foreign and Swedish variables.

Variable		Data	Posterior distribution Percentile 5	12.5	50	87.5	95	
Foreign (KIX20)	Sweden							
Policy rate	Policy rate	0.92	0.39	0.51	0.73	0.86	0.90	Improve
Corporate spread	Corporate spread	0.86	0.21	0.34	0.59	0.77	0.82	Similar
GDP	GDP	0.68	0.27	0.32	0.43	0.52	0.56	Improve
Unemployment rate	Unemployment rate	0.67	0.02	0.15	0.42	0.63	0.70	Improve
Employment	Employment	0.63	0.08	0.21	0.48	0.68	0.74	Improve
GDP	Imports	0.66	0.24	0.29	0.40	0.50	0.55	Improve
GDP	Exports	0.62	0.17	0.22	0.34	0.45	0.49	Improve
Consumption	Consumption	0.52	0.29	0.34	0.45	0.55	0.59	Improve
Investment	Investment	0.47	-0.06	0.06	0.15	0.28	0.34	Similar
CPI	CPIF	0.40	0.14	0.19	0.31	0.42	0.47	Similar
Foreign (KIX20)	Foreign (KIX20)							
GDP	Investment	0.82	0.54	0.58	0.67	0.74	0.77	Similar
GDP	Consumption	0.71	0.46	0.50	0.61	0.70	0.73	Similar
CPIxe	Policy rate	0.58	-0.25	-0.12	0.20	0.47	0.58	Similar
CPI	Wage	0.51	-0.08	-0.02	0.12	0.25	0.31	Improve
Employment	Wage	0.50	-0.09	0.00	0.24	0.45	0.53	Improve
Sweden	Sweden							
Wage	Policy rate	0.71	-0.25	-0.17	0.04	0.26	0.34	Worse
Exports	Imports	0.70	0.33	0.38	0.48	0.57	0.61	Similar
GDP	Exports	0.65	0.40	0.44	0.53	0.62	0.65	Improve
GDP	Investment	0.49	0.32	0.37	0.47	0.56	0.60	Improve
GDP	Real exchange rate	-0.39	-0.34	-0.28	-0.16	-0.04	0.02	Worse

Based on 5,000 thinned parameter draws from the joint posterior distribution (every 200th draw from a chain of length 1,000,000). For each parameter draw an artificial data sample of size T=95 is simulated using the model and the sample contemporaneous correlation is computed. In the table, the distribution of model sample correlations are characterised through percentiles.

Table 18: Modified posterior distributions of contemporaneous population correlations, foreign and Swedish variables.

Variable		Data	Modified posterior distribution					
			Percentile					
			5	12.5	50	87.5	95	
Foreign (KIX20)	Sweden							
Policy rate	Policy rate	0.92	0.81	0.82	0.85	0.87	0.88	Similar
Corporate spread	Corporate spread	0.86	0.47	0.54	0.66	0.76	0.79	Similar
GDP	GDP	0.68	0.40	0.41	0.43	0.46	0.47	Improve
Unemployment rate	Unemployment rate	0.67	0.37	0.38	0.42	0.45	0.47	Improve
Employment	Employment	0.63	0.37	0.40	0.45	0.49	0.51	Improve
GDP	Imports	0.66	0.36	0.37	0.40	0.43	0.44	Improve
GDP	Exports	0.62	0.30	0.31	0.34	0.37	0.38	Improve
Consumption	Consumption	0.52	0.40	0.42	0.46	0.50	0.52	Improve
Investment	Investment	0.47	0.08	0.10	0.14	0.19	0.20	Improve
CPI	CPIF	0.40	0.26	0.27	0.30	0.34	0.35	Improve
Foreign (KIX20)	Foreign (KIX20)							
GDP	Investment	0.82	0.64	0.65	0.67	0.69	0.70	Similar
GDP	Consumption	0.71	0.57	0.59	0.62	0.65	0.66	Similar
CPIxe	Policy rate	0.58	0.13	0.14	0.16	0.18	0.20	Similar
CPI	Wage	0.51	0.11	0.13	0.15	0.18	0.19	Improve
Employment	Wage	0.50	0.14	0.16	0.20	0.25	0.27	Worse
Sweden	Sweden							
Wage	Policy rate	0.71	0.01	0.02	0.04	0.07	0.08	Worse
Exports	Imports	0.70	0.45	0.46	0.48	0.50	0.51	Similar
GDP	Exports	0.65	0.36	0.37	0.40	0.43	0.44	Similar
GDP	Investment	0.49	0.44	0.45	0.47	0.49	0.50	Improve
GDP	Real exchange rate	-0.39	-0.22	-0.20	-0.16	-0.13	-0.11	Worse

Based on 5,000 thinned parameter draws from the joint posterior distribution (every 200th draw from a chain of length 1,000,000). For each parameter draw the population/theoretical correlation is computed. In the table, the distribution of model population/theoretical correlations are characterised through percentiles.

Table 19: Forecast error variance decomposition (FEVD). Foreign (KIX20) variables. Eight quarter horizon. Computed for posterior mode parameter and modified posterior mode parameter (in parentheses).

	Shock/Variable	$\Delta Y_t^{*,a}$	U_t^*	$\Delta W_t^{*,a}$	$\pi_t^{*,c,a}$	R_t^*
$\hat{\epsilon}_t^*$	Temporary technology	0 (0)	1 (1)	0 (0)	0 (0)	1 (1)
$\hat{\Upsilon}_t^*$	Temporary marginal efficiency of inv.	26 (34)	53 (59)	4 (3)	1 (0)	28 (31)
$\hat{\mu}_{z^*,t}$	Permanent technology	55 (47)	2 (2)	17 (6)	13 (3)	1 (1)
$\hat{\lambda}_t^*$	Price markup	2 (1)	6 (2)	1 (0)	25 (14)	1 (0)
$\hat{\lambda}_t^{w,*}$	Wage markup	1 (0)	1 (0)	70 (34)	10 (0)	1 (0)
$\hat{\zeta}_t^{c,*}$	Consumer preference	5 (4)	8 (4)	0 (0)	0 (0)	4 (2)
$\hat{\zeta}_t^{n,*}$	Labour supply	2 (3)	2 (1)	0 (0)	0 (0)	1 (1)
$\hat{\chi}_t^*$	Household risk premium	1 (2)	7 (7)	1 (2)	1 (0)	11 (12)
$\hat{\varepsilon}_{R,t}^*$	Monetary policy	2 (2)	12 (8)	6 (4)	2 (0)	0 (0)
$\hat{p}_t^{ce,*}$	Relative price of energy	1 (1)	4 (3)	0 (0)	48 (59)	0 (0)
$\widehat{\bar{\pi}}_t^*$	Inflation target/trend	0 (2)	0 (8)	0 (50)	0 (23)	0 (5)
$\hat{g}_t^*$	Government consumption	4 (4)	4 (3)	0 (0)	0 (0)	2 (1)
z_t^*	Real interest rate trend	0 (0)	0 (0)	0 (0)	0 (0)	49 (45)

U_t), annual wage inflation ($\Delta W_t^{*,a}$,ΔW_t^a), annual headline inflation ($\pi_t^{*,c,a}$, $\pi_t^{c,a}$) and the policy rate (R_t^*,R_t). The FEVDs are computed for the posterior mode parameter and the modified posterior mode parameter (in parenthesis). In the working paper we report FEVDs where the foreign and domestic innovations are aggregated into two groups while here we study the variance shares of individual innovations.[8]

For the foreign economy we make the following broad observations. First, overall, the permanent technology shock is the most important supply shock, while the marginal efficiency of investment shock is the main demand shock.[9] Second, CPI inflation is mainly driven by energy price shocks, price and wage markup shocks and shocks to permanent technology. Third, shocks to the real interest rate trend and investment shocks are important for the variation in the policy rate.

For the domestic variables (Table 20) we make the following broad observations. First, global shocks to permanent technology and the real interest rate trend, and the foreign investment shock are the three most important foreign shocks in explaining the variation in domestic variables. Second, shocks to energy prices, domestic and imported consumption markups, the inflation trend and the UIP exchange rate risk premium are important in accounting for the variation in CPIF inflation. Third, shocks to the real interest rate trend are important for the variation in the repo rate.

5 Impulse responses

Here we display the impulse responses to some of the more important shocks in the model, as judged by the variance decompositions (or alternatively the historical decompositions). The responses are shown for GDP, consumption, investment, exports, imports, employment, and the real exchange rate in levels, and percent deviation from steady state. Wage and price inflation are in annual percent change. The policy rate is in percentage points. In Figure 4, the impulse responses to a global permanent technology shock are displayed. In Figure, 5 the impulse responses to a foreign investment

[8] With independent shocks one can equivalently discuss variance contributions from shocks and innovations. Here we attempt to be exact and refer to contributions from *innovations* since the model contains correlated shocks.

[9] Supply shocks are those which move output and inflation in opposite directions, while demand shocks affect both variables in the same direction.

Table 20: Forecast error variance decomposition (FEVD). Swedish variables. Eight quarter horizon. Computed for the posterior mode parameter and modified posterior mode parameter (in parentheses).

	Shock/Variable	ΔY_t^a	U_t	ΔW_t^a	Q_t	$\pi_t^{c,a}$	R_t
	Foreign						
$\hat{\epsilon}_t^*$	Temporary technology	1 (2)	1 (1)	0 (0)	2 (4)	0 (0)	0 (1)
$\hat{\Upsilon}_t^*$	Temporary marginal efficiency of inv.	6 (16)	8 (19)	0 (1)	0 (0)	0 (0)	6 (13)
$\hat{\mu}_{z^*,t}$	Permanent technology	26 (30)	2 (4)	5 (3)	11 (17)	16 (12)	2 (3)
$\hat{\lambda}_t^*$	Price markup	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
$\hat{\lambda}_t^{w,*}$	Wage markup	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
$\hat{\zeta}_t^{c,*}$	Consumer preference	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
$\hat{\zeta}_t^{n,*}$	Labour supply	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
$\hat{\chi}_t^*$	Household risk premium	0 (1)	1 (2)	0 (0)	0 (0)	0 (0)	3 (4)
$\hat{\varepsilon}_{R,t}^*$	Monetary policy	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
$\hat{p}_t^{ce,*}$	Relative price of energy	0 (0)	0 (1)	0 (0)	1 (2)	6 (12)	0 (0)
$\hat{\bar{\pi}}_t^*$	Inflation target/trend	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
$\hat{g}_t^*$	Government consumption	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
z_t^*	Real interest rate trend	0	0	0	0	0	28 (29)
	Foreign, total	34 (49)	13 (27)	5 (4)	17 (25)	22 (25)	40 (51)
	Domestic						
$\hat{\epsilon}_t$	Temporary technology	1 (1)	21 (29)	0 (1)	6 (7)	0 (1)	15 (18)
$\hat{\Upsilon}_t$	Temporary marginal efficiency of inv.	5 (6)	6 (4)	0 (0)	0 (0)	0 (0)	4 (3)
$\hat{\lambda}_t^d$	Domestic price markup	1 (1)	2 (1)	0 (0)	1 (0)	27 (23)	0 (0)
$\hat{\lambda}_t^{m,c}$	Import consumption markup	0 (0)	0 (0)	0 (0)	1 (1)	5 (6)	0 (0)
$\hat{\lambda}_t^{m,i}$	Import investment markup	3 (2)	2 (4)	0 (0)	0 (0)	0 (0)	1 (3)
$\hat{\lambda}_t^{m,x}$	Import-in-export markup	16 (11)	14 (8)	0 (0)	2 (1)	0 (0)	10 (5)
$\hat{\lambda}_t^x$	Export markup	10 (12)	8 (8)	0 (0)	0 (1)	0 (0)	5 (5)
$\hat{\lambda}_t^w$	Wage markup	0 (1)	0 (1)	70 (90)	0 (0)	3 (6)	0 (0)
$\hat{\zeta}_t^c$	Consumer preference	2 (2)	2 (2)	0 (0)	0 (0)	0 (0)	1 (1)
$\hat{\zeta}_t^n$	Labour supply	0 (0)	3 (4)	0 (0)	1 (0)	0 (0)	2 (2)
$\hat{\chi}_t$	Household risk premium	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)
$\hat{\varepsilon}_{R,t}$	Monetary policy	0 (1)	4 (4)	1 (1)	1 (2)	0 (1)	3 (4)
$\hat{\bar{\pi}}_t^c$	Inflation target/trend	0 (0)	2 (0)	23 (4)	0 (0)	17 (7)	1 (0)
$\hat{p}_t^{d,ce}$	Relative price of energy	0 (0)	0 (0)	0 (0)	1 (1)	18 (23)	0 (0)
$\hat{g}_t$	Government consumption	26 (12)	21 (7)	0 (0)	1 (0)	0 (0)	14 (4)
$\hat{\tilde{\phi}}_t$	Country exch. rate. risk premium	0 (0)	0 (1)	0 (0)	68 (61)	7 (9)	1 (2)

shock are displayed. In Figure 6, the impulse responses to a shock to the foreign relative price of energy are displayed. In Figure 7, the impulse responses to a domestic monetary policy shock are displayed. While the monetary policy shock is not important from the perspective of the variance decompositions it is obviously an important shock for a central bank since it illustrates the monetary policy transmission mechanism. The impulse responses are computed for the posterior (solid lines) and modified posterior mode (dotted lines) parameter vectors.

6 Estimates of unobservables

In Figure 8, the smoothed (i.e. t|T) estimates of selected foreign (blue) and domestic (red) variables, computed for the posterior mode parameter and the period 1995:2–2018:4, are displayed. Output ($\hat{y}_t$ and $\hat{y}_t^*$), employment ($\hat{N}_t$ and $\hat{N}_t^*$), the real wage ($\widehat{\bar{w}}_t$ and $\widehat{\bar{w}}_t^*$), real marginal cost ($\widehat{mc}_t^d$ and $\widehat{mc}_t^*$), and the real exchange rate ($\hat{q}_t$) are in percent deviation from steady state (i.e. the log deviation from steady state has been multiplied by 100). The inflation ($\widehat{\bar{\pi}}_t^c$ and $\widehat{\bar{\pi}}_t^*$), policy rate ($\hat{R}_t^t$ and $\hat{R}_t^{t,*}$) and real policy rate trends ($\widehat{\bar{R}}_t^t$ and $\widehat{\bar{R}}_t^{t,*}$) are in percent (here we have multiplied by 400 and added the steady state such that the variables can more easily be related to data). The policy rate gap ($\hat{R}_t$ and $\hat{R}_t^*$) is the percentage point deviation between the policy rate and the policy rate trend.

We make the following broad observations on the smoothed estimates. First we note that the employment gaps and the real exchange rate have observable counterparts and they should therefore directly reflect the respective data series. The foreign and domestic output and employment gaps suggest that resource utilization is fairly close to normal at the end of the sample period in 2018. The estimate of domestic real marginal cost is well correlated with the standard data measure of the labour share in the whole economy (the measure of the labour share is not shown here). The domestic inflation trend has contributed to low inflation over a long period and illustrates the difficulty in understanding the low, i.e. on average below target, inflation in Sweden. The foreign and domestic policy rate trends are almost identical (by construction) and capture the decline in real and nominal interest rates in the data.

In Figure 9, smoothed estimates of foreign (blue) and domestic (red) headline ($\hat{\pi}_t^c$ and $\hat{\pi}_t^{c,*}$), core ($\hat{\pi}_t^{cxe}$ and $\hat{\pi}_t^{cxe,*}$), energy ($\hat{\pi}_t^{ce}$ and $\hat{\pi}_t^{ce,*}$), consumption import excluding energy ($\hat{\pi}_t^{m,c}$), domestic excluding energy ($\hat{\pi}_t^d$), domestic energy ($\hat{\pi}_t^{d,ce}$) and imported energy ($\hat{\pi}_t^{m,ce}$) inflation in percent, and the relative price of energy ($\hat{p}_t^{ce}$ and $\hat{p}_t^{ce,*}$), in percent deviation from steady state, are displayed. We have multiplied the model inflation rates by 400 and added the respective steady states. Again the purpose is to make the series more readily comparable to the data. As noted in the working paper, all inflation series are either observed or implicitly observed.

7 Model specification sensitivity analysis

In the model development phase, a large set of alternative model specifications have been considered and estimated. In this section we compile and report the log Bayes factors, i.e. the log marginal likelihood difference with respect to the baseline, for a subset of these alternative model specifications. Our main objective is to learn more about which features of the model that are important (or not important) for the overall data fit. In each of the experiments we change one feature of the model, re-estimate the model and then compare the marginal likelihoods of the alternative and baseline specifications. The alternative posterior is optimised and the marginal likelihood is approximated using the Laplace approximation. While we do not provide an exhaustive discussion of the alternative specifications and the comparisons with the baseline, the results from these comparisons may be used to support some of the specification choices discussed in the working paper. A scale for interpretation

Figure 4: Impulse responses to a global permanent technology shock. Posterior mode (solid) and modified posterior mode (dotted).

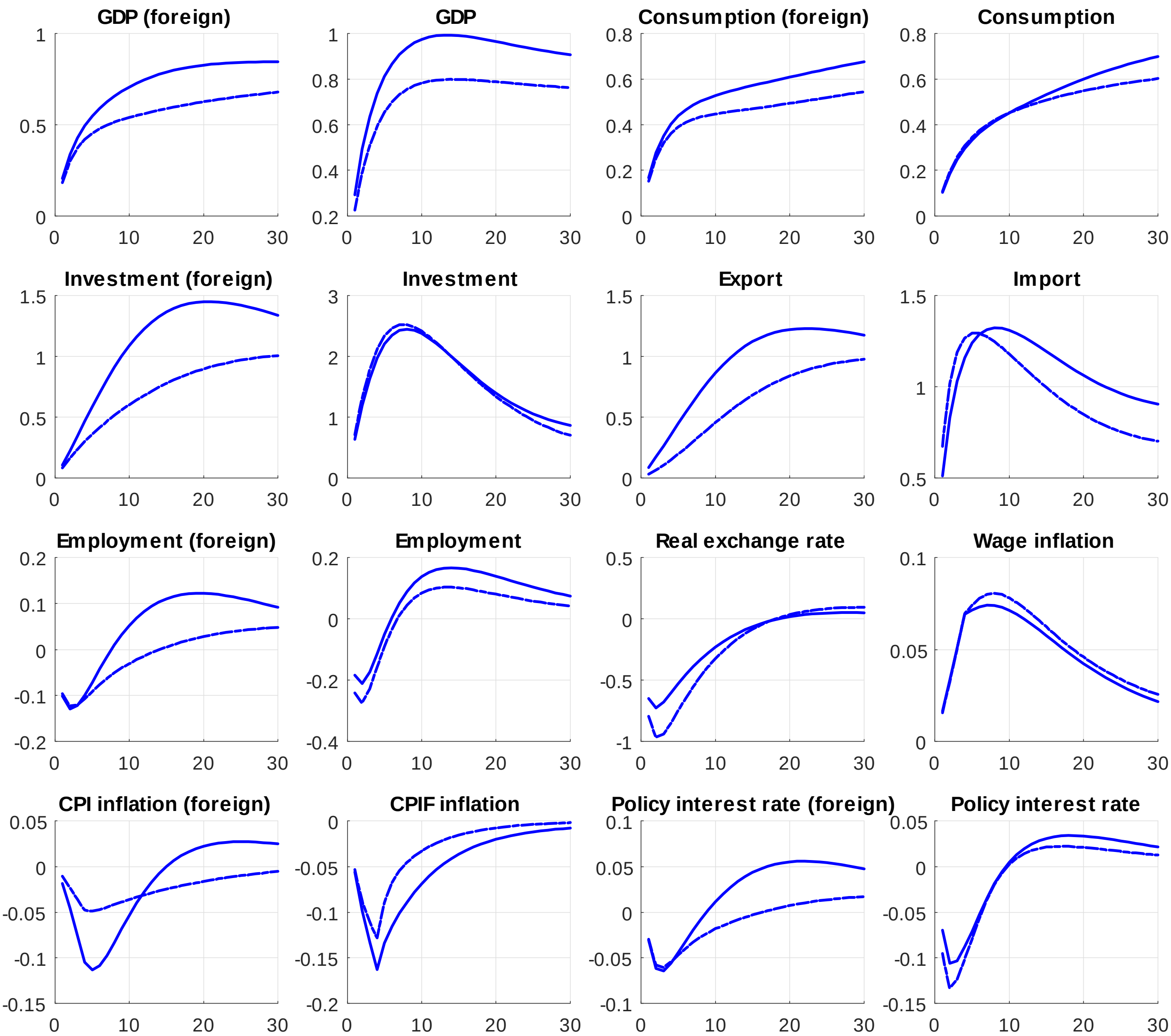


Figure 5: Impulse responses to a foreign marginal efficiency of investment shock. Posterior mode (solid) and modified posterior mode (dotted).

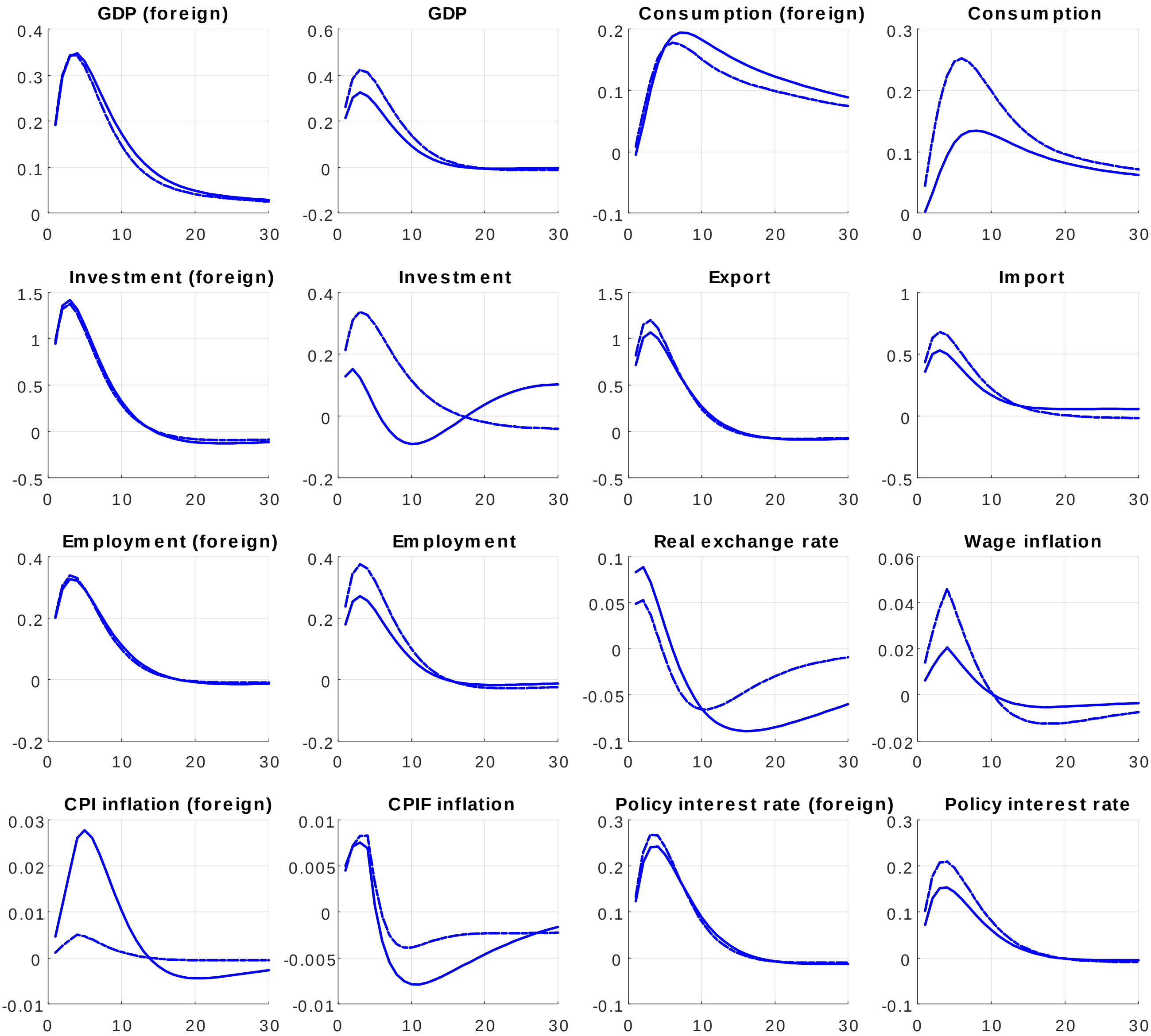


Figure 6: Impulse responses to a shock to the foreign relative price of energy. Posterior mode (solid) and modified posterior mode (dotted).

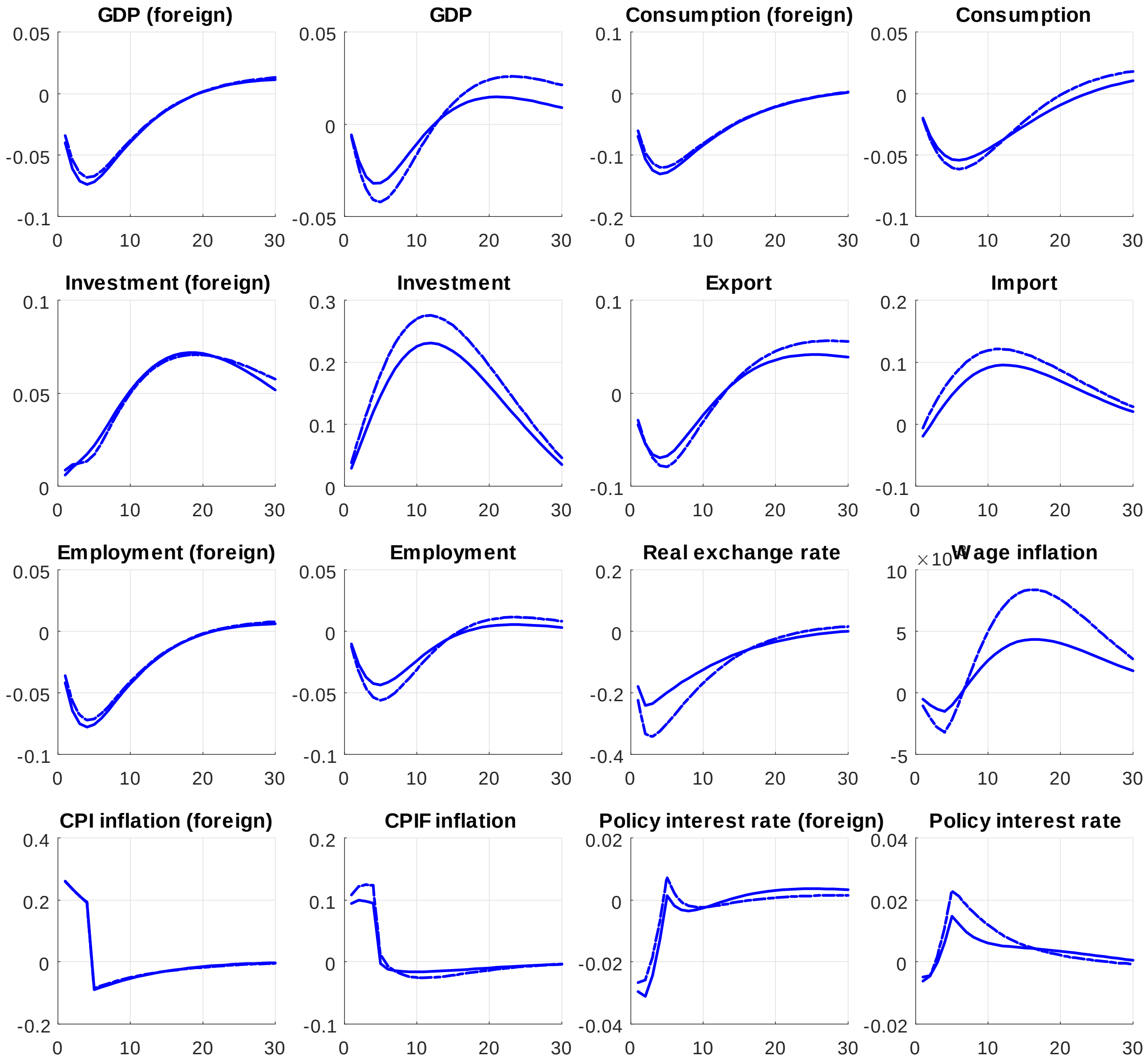


Figure 7: Impulse responses to a domestic monetary policy shock. Posterior mode (solid) and modified posterior mode (dotted).

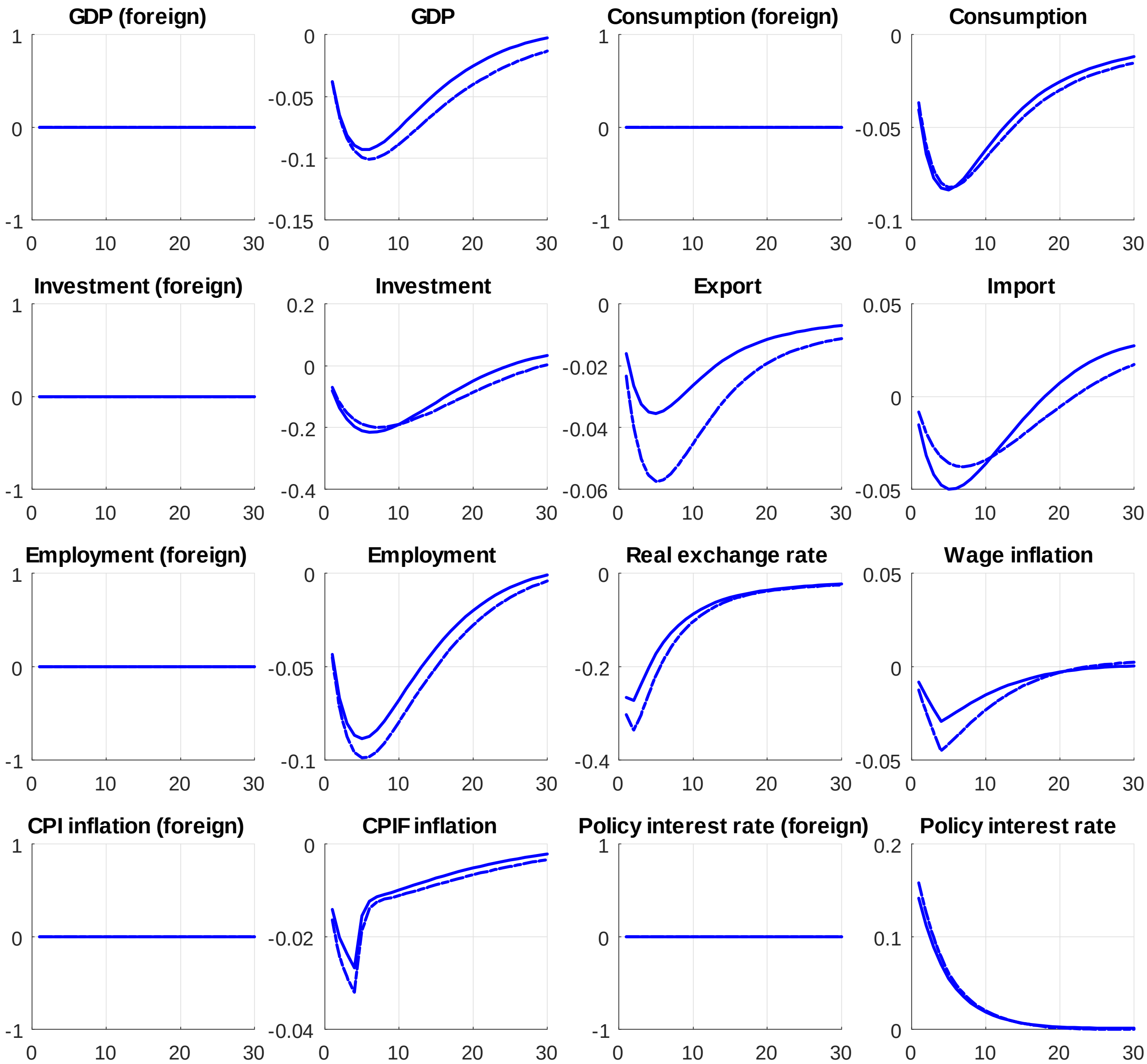


Figure 8: Smooth (t|T) estimates of foreign (blue) and domestic (red) variables. Computed for posterior mode parameter.

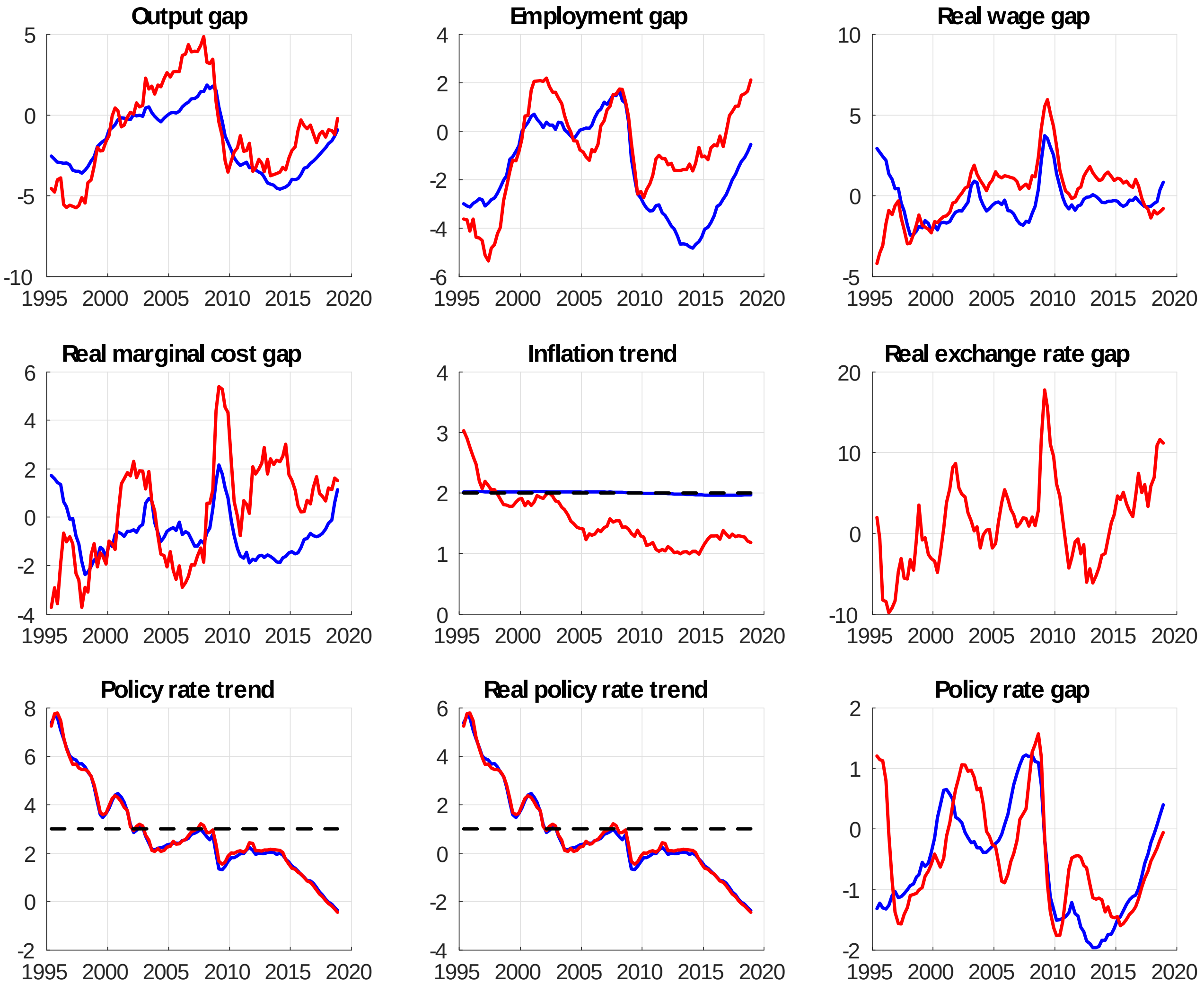
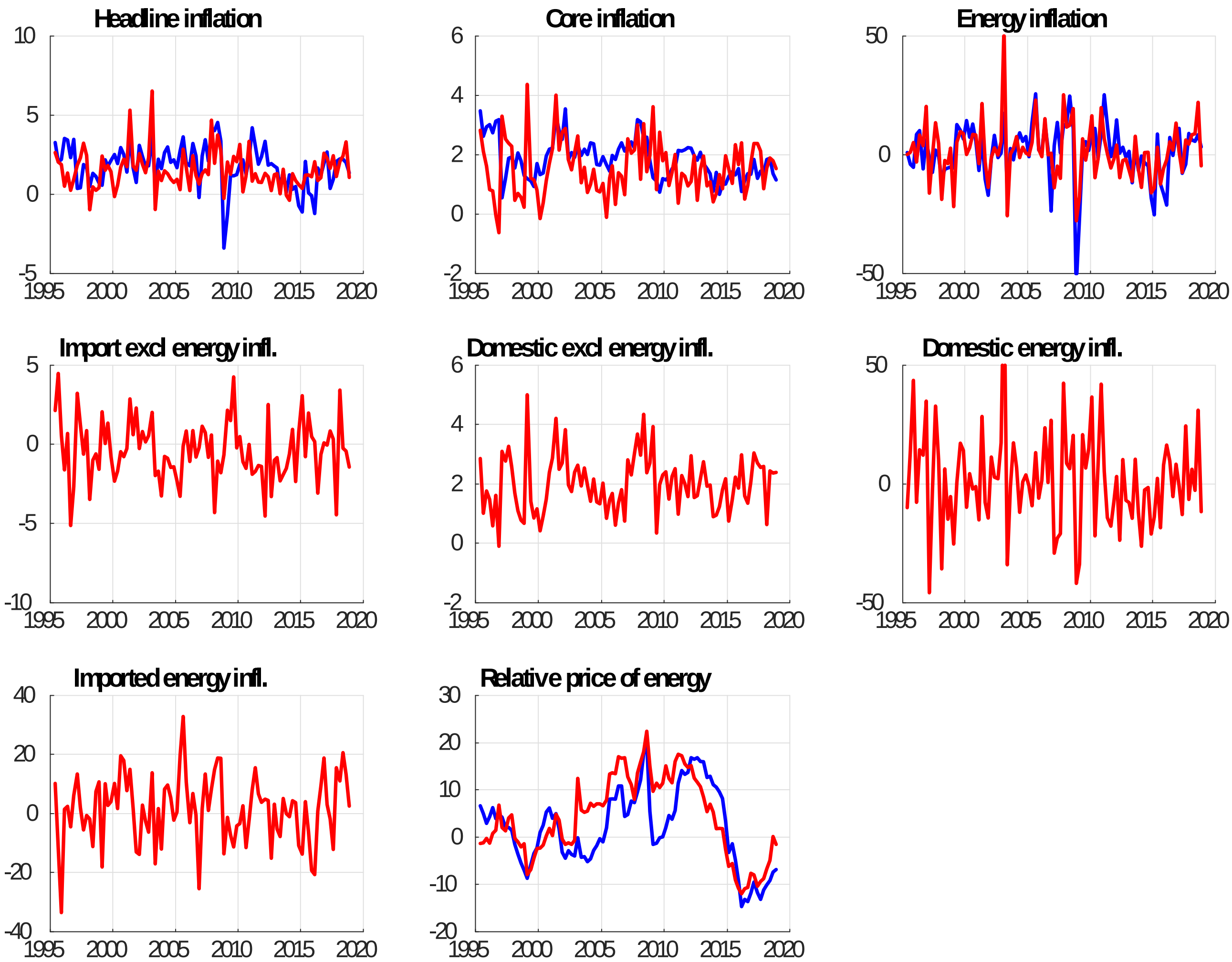


Figure 9: Smoothed estimates (t|T) of inflation and components of inflation. Foreign (blue) and domestic (red) variables.



of the Bayes factor is provided in the working paper.[10]

The alternative specifications are typically constructed in either of the following two ways. First, a parameter which is estimated in the baseline specification is instead calibrated to an extreme value which means the model feature in question is shut down. Second, a parameter which is calibrated in the baseline specification is instead estimated, which means the model specification is made more flexible. In these instances we use a fairly tight prior centered on the calibrated value in the baseline model (while the prior distribution is not reported below).

7.1 The foreign model

In Table 21 we report model sensitivity analysis for the foreign (sub-)model estimated using foreign data. The estimated baseline foreign model is presented in the working paper (it is obtained through estimation of the marginal posterior of the foreign economy parameters of the two-region model).

The results of the experiments reported in the table can be briefly described as follows. The ARMA(1,1) specification for the wage markup and real interest rate trend shocks are supported by the data. If AR(1) processes are instead assumed for these shocks by calibrating the MA coefficients as $\theta_{z^*} = \theta_{\lambda^{w,*}} = 0$ the log marginal likelihood drops by 13 units compared to the baseline specification with ARMA shocks.

Estimating, rather than calibrating, the depreciation rate (δ^*), the capital share (α^*), wage indexation (κ_w^*), the parameter governing the wealth effect on labour supply (ν^*), steady-state technology growth (μ_z^*) or the excess trend for wages ($c^{\Delta w^*}$) does not affect the marginal likelihood much. This suggests that the calibrations of these parameters in the baseline model are not substantially at odds with the data. Estimating the parameter governing the wealth effect on labour supply (ν^*) yields an estimate close to 1, while its value appears largely unimportant for overall fit. Assuming deterministic rather than stochastic technology growth ($\sigma_{\mu_z^*} = 0$) lowers the marginal likelihood substantially. This suggests that modelling secular productivity growth using a stochastic trend, i.e. including the permanent technology shock, is important. This result is not surprising in the light of e.g. the variance decompositions reported above. Removing the shock to the real interest rate trend ($\sigma_{z^*} = 0$) also substantially worsens the fit, i.e. it is important to incorporate the real interest rate trend in the model. Replacing the consumer preference shock by an AR(1) shock to the discount rate reduces the marginal likelihood somewhat. Removing the dependence of the policy rate on either the level of unemployment ($r_{RU^*} = 0$) or the change in unemployment ($r_{\Delta RU^*} = 0$) also lowers the marginal likelihood substantially. These experiments illustrate that the specification of the monetary policy rule is important. Removing the inflation trend shock has no effect on the overall fit of the model.

7.2 The two-region model

In Table 22, specification sensitivity analysis for the two-region model estimated using Bayesian methods and foreign (KIX20) and Swedish data is reported. The results are briefly described in the following. Estimating, rather than calibrating, the import shares ($\tilde{\omega}$), excess trends (c), the domestic steady-state investment specific technology growth (μ_Ψ) or the indexation parameters (κ) has a relatively modest effect on the marginal likelihood. Next, we report additional experiments where the priors of the Calvo parameters (ξ) in the model are altered; see also the discussion in the working paper. These experiments illustrate that even if the Calvo parameter priors are centered on lower values, the posterior mode estimates are typically large, i.e. the data strongly suggests large parameter values. Centering the priors of the elasticities of substitution (η) on a higher value, 1.5, the

[10] In some instances, i.e. for some alternative specifications, we have judged that the results are unreliable due to different reasons and these results are therefore not reported. We use univariate contour plots around the mode (so called check plots in Dynare) to support that the posterior mode has actually been located. We also run a short chain to verify that the acceptance rate is satisfactory, i.e. not too low. Since the covariance of the normal proposal density of the random walk Metropolis algorithm is based on the hessian evaluated at the posterior mode this also provides some assurance on the quality of the Laplace approximation of the marginal likelihood.

Table 21: Alternative specifications of the foreign submodel. Bayes factor comparison with the baseline model. A positive (negative) Bayes factor means that the alternative (baseline) is preferred.

Modification vs. baseline	Alt. calibration or posterior mode	Log Bayes factor
Baseline		0
All shocks AR(1)	$\theta_{z^*} = \theta_{\lambda^{w,*}} = 0$	-13
Est. depreciation rate	$\delta^* = 0.014$	-1
Est. capital share	$\alpha^* = 0.20$	1
Est. wage indexation	$\kappa_w^* = 0.24$	1
Est. wealth effect on lab supply	$\nu^* = 0.90$	-2
Cal. wealth effect on lab supply	$\nu^* = 0$	-1
Disc. shock $\hat{\zeta}_t^{\beta,*}$, no cons $\hat{\zeta}_t^{c,*}$	$\sigma_{\zeta^{c,*}} = 0$, est $\hat{\zeta}_t^{\beta,*}$	-7
Det. trend growth	$\sigma_{\mu_z^*} = 0$	-47
Det. tr. growth & no int. rate tr.	$\sigma_{\mu_z^*} = 0$ and $\sigma_{z^*} = 0$	-83
No working capital	$\nu^{wc,*} = 0$	1
Est. wage excess trend, N(0,1) pr	$c^{\Delta w^*} = -0.81$	-1
Est. ss techn. growth	$400 \ln(\mu_z^*) = 1.47\%$	2
Mon. policy rule, no unempl.	$r_{RU^*} = 0$	-33
Mon. policy rule, no unempl. ch.	$r_{\Delta RU^*} = 0$	-22
No inflation trend shock	$\sigma_{\bar{\pi}^{c,*}} = 0$	0
Est. price markup shock AR(1)	$\rho_{\lambda^*} = 0.59$	-2

posterior mode estimates of these parameters increase, while the marginal likelihood decreases quite substantially. The main takeaway, however, is probably that these parameters are not well identified. Using priors for the shock correlations ($c_{i,j}$) which are centered on zero we note that most shock correlations are yet estimated to be positive, while the marginal likelihoods are lower than in the baseline specification (where we have Beta priors centered on 0.5). While we do not fully understand why the marginal likelihoods are lower with normal priors on the shock correlations, the main result is that the correlations are still generally estimated to be positive. The working capital channel (ν) does not appear to be that important, judged by the marginal likelihood for the different specifications. Finally, dependence of the foreign and domestic real interest rate trends on permanent technology growth is not supported by the data. The parameter on technology growth is estimated to be low, using two quite different priors, and the marginal likelihoods are substantially lower compared to the baseline specification. One interpretation of these experiments is that variations in trend productivity growth is not an important factor in accounting for the trend decline in interest rates.

Table 22: Alternative specifications of the two-region DSGE model. Bayes factor comparison with the baseline model. A positive (negative) Bayes factor means that the alternative (baseline) is preferred.

Modification vs. baseline	Alt. calibration or posterior mode	Log BF
Baseline	-	0
Est. import and energy shares	$\tilde{\omega}_c = 0.27$, $\tilde{\omega}_i = 0.40$, $\tilde{\omega}_e = 0.075$, $\tilde{\omega}_{em} = 0.49$	-3
Est. excess trends	$c^{\Delta w^*} = -0.89$, $c^{\Delta Y} = 0.15$, $c^{\Delta w} = -0.05$, $c^{mcxe} = -2.19$, $c^{cxe} = -0.22$	5
Est μ_Ψ and $c^{\Delta Y}$	$400 \ln(\mu_\Psi) = 0.90$, $c^{\Delta y} = 0.10$	-1
Est index. param. B(0.5,0.2)	$\kappa_{mc} = 0.14$, $\kappa_{mi} = 0.54$, $\kappa_x = 0.21$, $\kappa_w^* = 0.16$, $\kappa_w = 0.08$	-8
Est. low Calvo prior, B(0.45,0.1)	$\xi^* = 0.93$, $\xi_w^* = 0.83$, $\xi_d = 0.93$, $\xi_{m,c} = 0.92$, $\xi_{m,i} = 0.74$, $\xi_{m,x} = 0.76, \xi_w = 0.84$, $\xi_x = 0.71$	-139
Est. low Calvo prior, B(0.45,0.075)	$\xi^* = 0.86$, $\xi_w^* = 0.80$, $\xi_d = 0.86$, $\xi_{m,c} = 0.86$, $\xi_{m,i} = 0.70$, $\xi_{m,x} = 0.71$, $\xi_w = 0.81$, $\xi_x = 0.67$	-195
Est medium Calvo prior, B(0.6,0.2)	$\xi^* = 0.98$, $\xi_w^* = 0.90$, $\xi_d = 0.94$, $\xi_{m,c} = 0.93$, $\xi_{m,i} = 0.78$, $\xi_{m,x} = 0.81$, $\xi_w = 0.88$, $\xi_x = 0.78$	8
Est medium Calvo prior, B(0.6,0.1)	$\xi^* = 0.96$, $\xi_w^* = 0.87$, $\xi_d = 0.93$, $\xi_{m,c} = 0.92$, $\xi_{m,i} = 0.77$, $\xi_{m,x} = 0.79$, $\xi_w = 0.86$, $\xi_x = 0.75$	-39
Est. high elast. of subst. G(1.5,0.5)	$\eta_c = 1.32$, $\eta_i = 0.47$, $\eta_f = 0.74$, $\eta_x = 1.82$	-17
No shock correlations	$c_{i,j} = 0$, nine shock corr. parameters	-22
Shock correlations N(0,0.5), trunc.	$c_{\epsilon,\epsilon^*} = 0.37$, $c_{p^{d,ce},p^{ce,*}} = 0.19$, $c_{g,g^*} = 0.47$, $c_{\Upsilon,\Upsilon^*} = -0.03$, $c_{\zeta^c,\zeta^{c,*}} = 0.23$, $c_{\zeta^n,\zeta^{n,*}} = 0.29$, $c_{\chi,\chi^*} = 0.69$, $c_{\tilde{\phi},\,-\mu_z^*} = 0.12$, $c_{\lambda^{m,i},\,-\mu_z^*} = 0.31$	-5
Shock correlations N(0,100), trunc.	$c_{\epsilon,\epsilon^*} = 0.42$, $c_{p^{d,ce},p^{ce,*}} = 0.23$, $c_{g,g^*} = 0.54$, $c_{\Upsilon,\Upsilon^*} = -0.04$, $c_{\zeta^c,\zeta^{c,*}} = 0.23$, $c_{\zeta^n,\zeta^{n,*}} = 0.44$, $c_{\chi,\chi^*} = 0.71$, $c_{\tilde{\phi},\,-\mu_z^*} = 0.12$, $c_{\lambda^{m,i},\,-\mu_z^*} = 0.31$	-46
No working capital	$\nu^{wc,*} = \nu^{wc,d} = \nu^{wc,m} = \nu^{wc,x} = 0$	-8
Est. working capital, B(0.5,0.2)	$\nu^{wc,*} = 0.46$, $\nu^{wc,d} = 0.69$, $\nu^{wc,m} = 0.50$, $\nu^{wc,x} = 0.55$	5
Real int. rate tr., techn. par. N(1,0.5)	$r_{\mu_{z+}} = 0.12$	-17
Real int. rate tr., techn. par. N(0,0.5)	$r_{\mu_{z+}} = 0.10$	-14

Note: a log Bayes factor <0 means that the baseline is favoured, while a log Bayes factor >0 means that the alternative specification is favoured.

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