Online Appendix

Appendix A Prior setup and posterior simulation

The approach to estimation and inference is Bayesian. We thus have to specify suitable prior distributions for all coefficients of the UC-SV model.

Point of departure is a normally distributed prior for the initial value of $\boldsymbol{f}_t = (\overline{\boldsymbol{f}}_t', \hat{\boldsymbol{f}}_t')'$,

$$\boldsymbol{f}_1 \sim \mathcal{N}(\boldsymbol{0}, \underline{\boldsymbol{V}}_f). \tag{1}$$

Here $\underline{\boldsymbol{V}}_f$ is a diagonal prior variance-covariance matrix where we set the diagonal elements equal to ten, implying that we are relatively uninformative about the specific value of the initial state of the system.

For the diagonal elements of $\boldsymbol{\Phi}$ we also impose a normally distributed prior. More specifically, we set

$$\phi_{ii} \sim \mathcal{N}(\underline{\phi}_{ii}, \underline{v}_{\phi ii}) \text{ for } i = 1, \ldots, 4, \tag{2}$$

with $\underline{\phi}_{ii}$ and $\underline{v}_{\phi_{ii}}$ denoting prior mean and variance, respectively. We center the prior means associated with the inflation gap to 0.75 and the corresponding prior variance to $(0.1)^3$.[1] In addition, we set the prior mean related to the unemployment gap to 0.99, with prior variance set equal to $(0.1)^3$. This tight prior implies that the inflation gap is less persistent than the unemployment gap. A prior setup that is relatively uninformative on the autoregressive coefficients of the gap components yields results that are qualitatively similar. However, inspection of the posterior draws reveals that the likelihood is relatively uninformative on the persistence, and we thus experimented with different values of the parameters for the US to match the results presented in Stella and Stock (2015).

We use a Gaussian prior for the free elements of $\boldsymbol{A}_t$,

$$a_j \sim \mathcal{N}(\underline{a}_j, \underline{v}_{a_j}) \tag{3}$$

where we set $\underline{a}_j$ equal to zero and $\underline{v}_{a_j}$ equal to $(0.1)^3$. Again, this prior specification

[1] This is broadly consistent with findings on the persistence of the inflation gap for the US before the Great Moderation (see Cogley and Sbordone 2008, Cogley et al. 2010).

places considerable mass on the prior view that the shocks to the state equations are uncorrelated. Being effectively uninformative about a_j yields similar results but at the cost that the MCMC algorithm mixes somewhat slower.

For the priors on the level of the log-volatility μ_i we impose a normal prior with mean $\underline{\mu}_i$ and variance $\underline{v}_{\mu i}$,

$$\mu_i \sim \mathcal{N}(\underline{\mu}_i, \underline{v}_{\mu_i}). \tag{4}$$

We set $\underline{\mu}_i = 0$ and $\underline{v}_{\mu_i} = 10^2$ for $i = 1, \ldots, 9$ to render this prior effectively uninformative. In addition, we impose a Beta prior on the persistence parameter ρ_i

$$\frac{\rho_i + 1}{2} \sim \mathcal{B}(b_0, b_1), \tag{5}$$

where we set $b_0 = 25$ and $b_1 = 5$ for all i leading to a prior mean of 0.83 with prior standard deviation of 0.07, thus placing considerable prior mass on high persistence regions of ρ_i. Note that this choice proves to be quite influential in practice since the likelihood typically carries little information about the persistence of the log-volatility.

Following Kastner and Frühwirth-Schnatter (2014) we use a non-conjugate Gamma prior on the variance of the log-volatility,

$$\vartheta_i \sim \mathcal{G}(1/2, \frac{1}{2B_\vartheta}). \tag{6}$$

The hyperparameter B_ϑ controls the tightness of the prior. It is straightforward to show that this prior implies

$$\pm\sqrt{\vartheta_i} \sim \mathcal{N}(0, B_\vartheta). \tag{7}$$

In the empirical application we set B_ϑ equal to unity. After experimenting with different values of B_ϑ, the specific choice of this hyperparameter proves to be rather unimportant in the present application. This prior setup has been motivated in Frühwirth-Schnatter and Wagner (2010) and provides several convenient properties. For instance, the Gamma prior does not bound ϑ_i away from zero and thus induces more shrinkage as the typical conjugate inverted Gamma prior.

For the elements of $\boldsymbol{\beta}$, we use the prior discussed in the third subsection of Section II.

The hyperparameters are chosen as follows.[2] For the spike variance, we use $\tau_{\pi 0} = 0.1 \times \hat{\sigma}_{\pi}^2$, where $\hat{\sigma}_{\pi}^2$ denotes the variance of the OLS estimator related to β_4. The slab variance is specified to equal $\tau_{\pi 1} = 10 \times \hat{\sigma}_{\pi}^2$, effectively rendering this prior weakly informative (conditional on δ_{π}).

Finally, we use an inverted Gamma prior for σ_{ν}^2,

$$\sigma_{\nu}^2 \sim \mathcal{IG}(c_0, c_1), \tag{8}$$

where c_0 and c_1 are set equal to $(0.1)^3$, rendering this prior effectively non-influential.

The Markov chain Monte Carlo algorithm iterates between the following steps:

- Simulate the full history of $\boldsymbol{f}_t$, denoted as $\boldsymbol{f}^T = (\boldsymbol{f}_1, \ldots, \boldsymbol{f}_T)'$ conditional on all other parameters and the data using the well-known algorithm developed by Carter and Kohn (1994) and Frühwirth-Schnatter (1994).
- The parameters of the log-volatility equation and the full history of log-volatilities $h_i^T = (h_{i1}, \ldots, h_{iT})'$ are simulated by means of the algorithm provided in Kastner and Frühwirth-Schnatter (2014), which proves to be an efficient alternative to other popular algorithms.[3]
- The autoregressive parameters of the state equations in Eq. (8) are sampled through Gibbs steps from their conditional Gaussian posterior distributions. To ensure stationarity we impose the constraint that all draws have to be smaller than unity in absolute values.
- Similarly, given the conjugacy of the prior setup employed, $\boldsymbol{\beta}$ is simulated from a normal distribution with well-known posterior mean and variance.
- The prior indicators δ_{π} and δ_{π}^* are simulated from Bernoulli distributions with a posterior restriction probability that takes a well known form (see, e.g., George and McCulloch 1993).
- For the covariance parameters a_j we follow Cogley and Sargent (2005) and rewrite the reduced-form errors as a set of simple regression models with innovations that are standard normally distributed. The normal prior on each a_j then yields a well-known

[2] Here we discuss the prior setup for domestic quantities only. For foreign quantities, we use the same hyperparameter values.

[3] This step is implemented using the `R` package stochvol (Kastner 2015a,b).

Gaussian posterior density with known moments that can be used to simulate a_j.

- Finally, σ_ν^2 is sampled with a Gibbs step by noting that the conditional posterior is of a well-known form, namely an inverted Gamma distribution.

In the empirical application we repeat this algorithm 30,000 times and discard the first 15,000 iterations as burn-ins. Moreover we impose the restriction that the variance of the unemployment gap at home and abroad equals to 0.3. Since allowing for stochastic volatility in the measurement error and the errors of the gap components separately typically leads to empirical problems, we fix the variance of $\hat{u}_t$ and $\hat{u}_t^*$. Again, setting the variance equal to 0.3 is predicated by calibrating the model to match the trend unemployment rate and unemployment gap estimated by previous studies for the US.

Appendix B Data

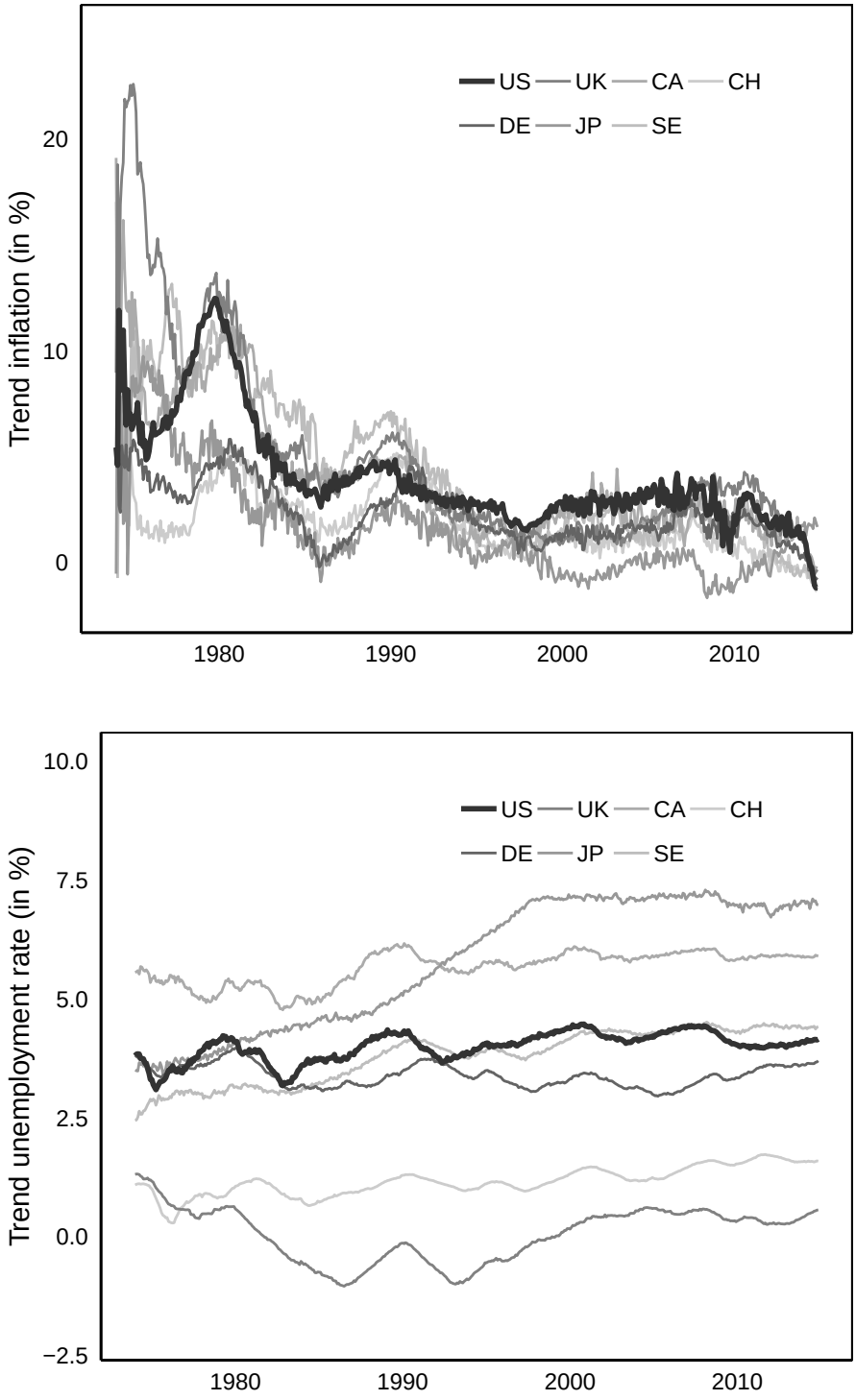
Table 1 — Data, sources, transformations

	Country	Identifier	Source	Comments
Exchange rates	CA	EXCAUS	FRB	
	JP	EXJPUS	FRB	
	SE	EXSDUS	FRB	
	CH	EXSZUS	FRB	
	UK	EXUSUK	FRB	Inverted
	DE	CCUSSP01DEM650N	MEI	Inverted, EUR/USD after euro changeover
CPI	CA	CANCPIALLMINMEI	MEI	Census X13 seas. adj.
	JP	JPNCPIALLMINMEI	MEI	Census X13 seas. adj.
	SE	SWECPIALLMINMEI	MEI	Census X13 seas. adj.
	CH	CHECPIALLMINMEI	MEI	Census X13 seas. adj.
	UK	GBRCPIALLMINMEI	MEI	Census X13 seas. adj.
	US	CPIAUCSL	BLS	
	DE	DEUCPIALLMINMEI	MEI	Census X13 seas. adj.
Unemployment rates	CA	LRUNTTTTCAM156S	MEI	
	JP	LRUN24TTJPM156N	MEI	Census X13 seas. adj.
	SE	LRHUTTTTSEM156S, SWEURHARMMDSMEI	MEI	Sources linked in 1983
	CH	LMUNRRTTCHM156N	MEI	Census X13 seas. adj.
	UK	LMUNRRTTGBM156S	MEI	
	US	UNRATE	BLS	
	DE		BA	Downloaded from Datastream
Short rates	CA	IR3TIB01CAM156N	MEI	Interbank rate
	JP	INTGSTJPM193N	IFS	T-Bill rate
	SE	IR3TIB01SEM156N	MEI	Linked with Riksbank data (see notes)
	CH	IR3TIB01CHM156N	MEI	Interbank rate
	UK	IR3TTS01GBM156N	MEI	T-Bill rate
	US	IR3TIB01USM156N	MEI	Interbank rate
	DE	IR3TIB01DEM156N	MEI	Interbank rate
Long rates	CA	IRLTLT01CAM156N	MEI	
	JP	INTGSBJPM193N	IFS	
	SE	IRLTLT01SEM156N	MEI	Linked with Riksbank data (see notes)
	CH	IRLTLT01CHM156N	MEI	
	UK	IRLTLT01GBM156N	MEI	
	US	IRLTLT01USM156N	MEI	
	DE	IRLTLT01DEM156N	MEI	
VIX	CA	TSX60	S&P	Start 10/2009
	JP			N/A
	SE			N/A
	CH	VSMI	SIX	Start 01/1999
	UK	.VFTSE	Datastream	Start 01/2000
	US	VIXCLS	FRED	Start 01/1990
	DE	.V1XI	Datastream	Start 12/1998
Policy uncertainty	CA		EPU	Start 01/1985
	JP		EPU	Start 01/1987
	SE		EPU	Start 01/1975
	CH		EPU	N/A
	UK		EPU	Start 01/1998
	US		EPU	Start 01/1985
	DE		EPU	Start 01/1993

Notes: All data, unless otherwise indicated, was retrieved from FRED, Federal Reserve Bank of St. Louis `https://research.stlouisfed.org/fred2/`. Data for short-term and long-term interest rates for Sweden was downloaded from `http://www.riksbank.se/en/The-Riksbank/Research/Historical-Monetary-Statistics-/Interest-and-stock-returns/`. Data for economic policy uncertainty indices were downloaded from `http://www.policyuncertainty.com/`.

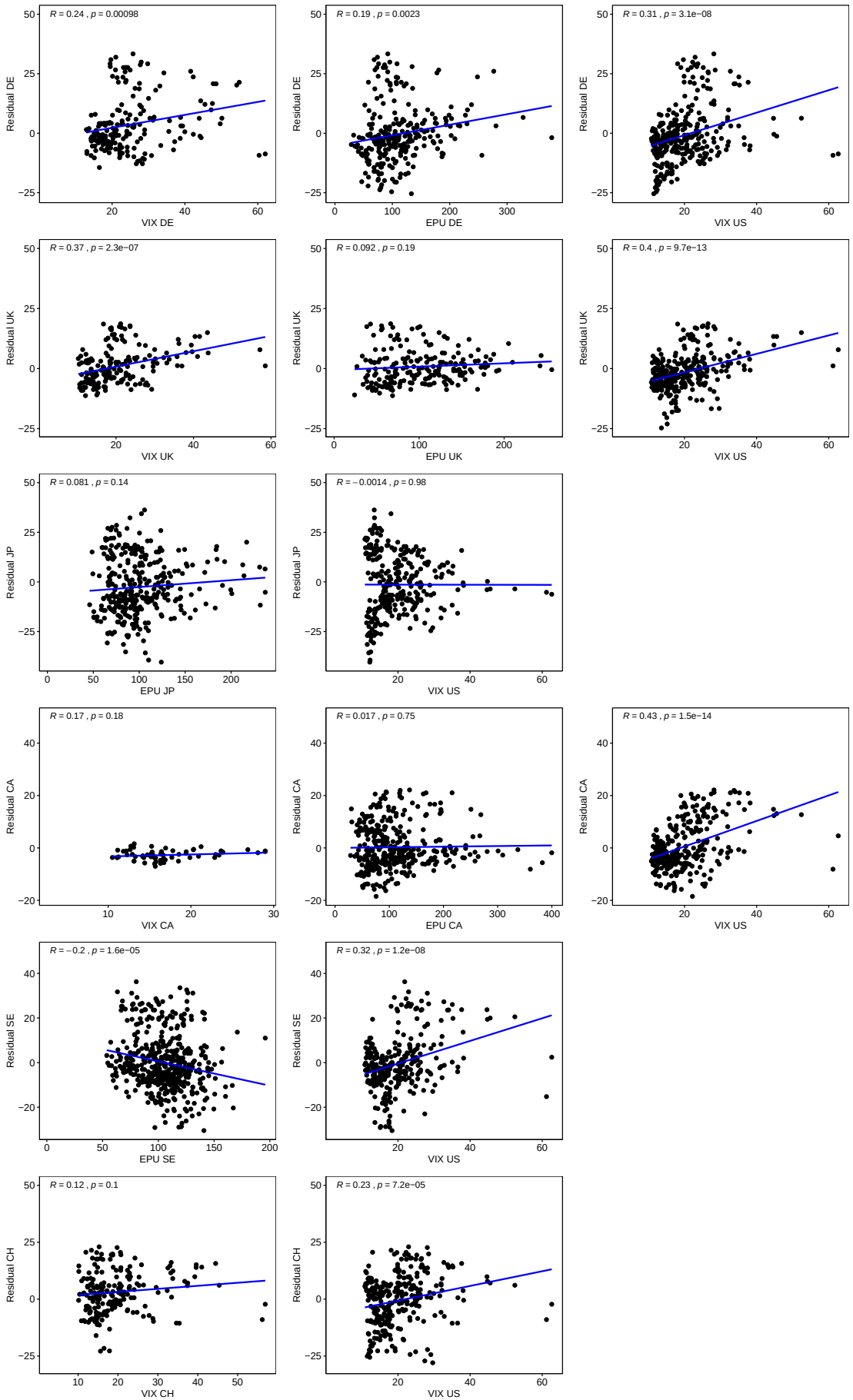
Appendix C Additional results and robustness tests

Figure 1 — Estimates of trends



Notes: Posterior mean of the estimated trend inflation rate (annualized) and trend unemployment rate. The results are based on 15,000 posterior draws.

Figure 2 — Correlation of residuals with uncertainty measures



Notes: Correlations of the residuals of the UC-SV model with various uncertainty measures (VIX and economic policy uncertainty; EPU). The sample range differs because most of the uncertainty measures start only in the 1990s or 2000s (see Appendix B).

Appendix C.1 Model without SV

Table 2 — Correlation with actual exchange rate (without SV)

		(A) Real		(B) Nominal	
		Log-level	Log-change	Log-level	Log-change
DEM/USD	Benchmark	0.42	0.02	0.73	0.03
		[0.36, 0.49]	[−0.08, 0.12]	[0.70, 0.78]	[−0.08, 0.13]
	UC-SV	0.44	0.03	0.74	0.04
		[0.36, 0.53]	[−0.04, 0.11]	[0.71, 0.78]	[−0.03, 0.11]
GBP/USD	Benchmark	0.28	0.02	0.62	0.04
		[0.20, 0.36]	[−0.06, 0.10]	[0.58, 0.69]	[−0.04, 0.12]
	UC-SV	0.34	0.03	0.64	0.04
		[0.26, 0.43]	[−0.04, 0.09]	[0.60, 0.69]	[−0.02, 0.10]
JPY/USD	Benchmark	0.44	0.00	0.88	0.03
		[0.37, 0.50]	[−0.08, 0.09]	[0.87, 0.92]	[−0.06, 0.11]
	UC-SV	0.47	0.00	0.89	0.02
		[0.35, 0.63]	[−0.06, 0.06]	[0.87, 0.92]	[−0.04, 0.08]
CAD/USD	Benchmark	0.56	0.04	0.66	0.06
		[0.51, 0.61]	[−0.05, 0.13]	[0.61, 0.74]	[−0.03, 0.14]
	UC-SV	0.57	0.05	0.66	0.06
		[0.45, 0.67]	[−0.02, 0.12]	[0.57, 0.74]	[−0.00, 0.13]
SEK/USD	Benchmark	0.52	0.04	0.72	0.05
		[0.46, 0.58]	[−0.03, 0.12]	[0.68, 0.79]	[−0.02, 0.13]
	UC-SV	0.57	0.05	0.75	0.06
		[0.51, 0.64]	[−0.01, 0.11]	[0.71, 0.79]	[0.00, 0.11]
CHF/USD	Benchmark	0.47	0.03	0.86	0.04
		[0.40, 0.53]	[−0.06, 0.11]	[0.84, 0.88]	[−0.04, 0.12]
	UC-SV	0.50	0.04	0.86	0.05
		[0.43, 0.57]	[−0.02, 0.10]	[0.85, 0.88]	[−0.01, 0.11]

Notes: Posterior mean correlation with actual US Dollar exchange rate. 5th and 95th percentiles in brackets. The benchmark model does not take into account changes in the inflation and unemployment trends.

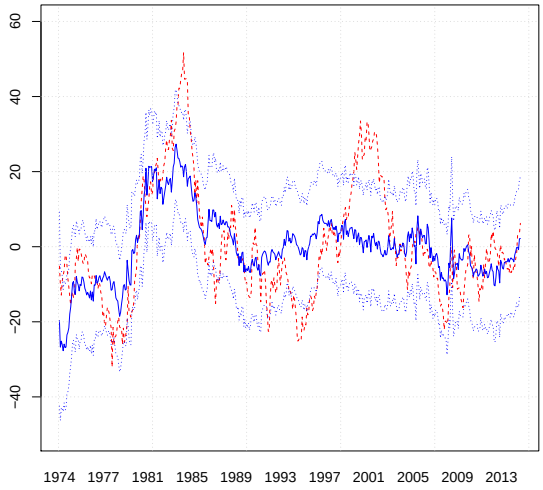
Table 3 — Autocorrelation real exchange rate (without SV)

		Log-level			Log-change		
		1st	2nd	3rd	1st	2nd	3rd
DEM/USD	Actual	0.98	0.96	0.93	0.01	0.04	0.04
	Benchmark	0.94	0.90	0.88	−0.14	−0.22	−0.02
	UC-SV	0.93	0.86	0.83	−0.09	−0.22	−0.06
GBP/USD	Actual	0.97	0.94	0.90	0.33	0.02	0.05
	Benchmark	0.90	0.82	0.78	−0.12	−0.17	−0.06
	UC-SV	0.93	0.86	0.82	−0.08	−0.15	−0.07
JPY/USD	Actual	0.99	0.96	0.94	0.33	0.08	0.05
	Benchmark	0.90	0.89	0.87	−0.42	−0.02	−0.01
	UC-SV	0.93	0.91	0.90	−0.42	−0.04	−0.02
CAD/USD	Actual	0.99	0.98	0.97	0.21	0.05	0.03
	Benchmark	0.95	0.91	0.89	−0.16	−0.12	−0.10
	UC-SV	0.95	0.91	0.89	−0.13	−0.12	−0.11
SEK/USD	Actual	0.99	0.97	0.95	0.36	0.04	0.05
	Benchmark	0.86	0.76	0.73	−0.12	−0.26	−0.10
	UC-SV	0.91	0.83	0.80	−0.11	−0.24	−0.10
CHF/USD	Actual	0.98	0.96	0.93	0.27	0.03	0.02
	Benchmark	0.94	0.91	0.90	−0.18	−0.25	−0.03
	UC-SV	0.95	0.93	0.92	−0.13	−0.22	−0.03

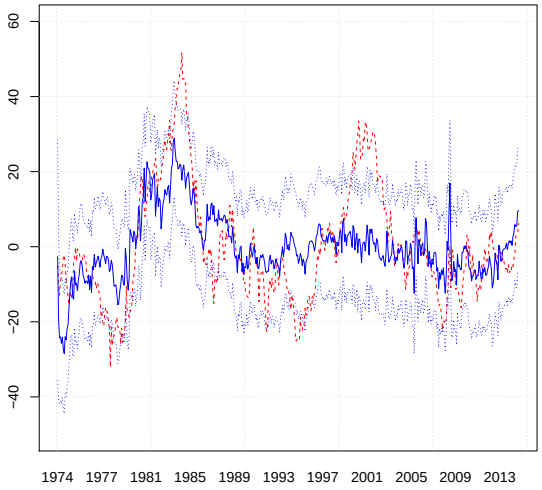
Notes: Sample autocorrelation function for the actual real US Dollar exchange rate and sample autocorrelation function for the posterior mean of the model predictions up to 3rd order. The benchmark model does not take into account changes in the inflation and unemployment trends.

Figure 3 — Model predictions for large economies

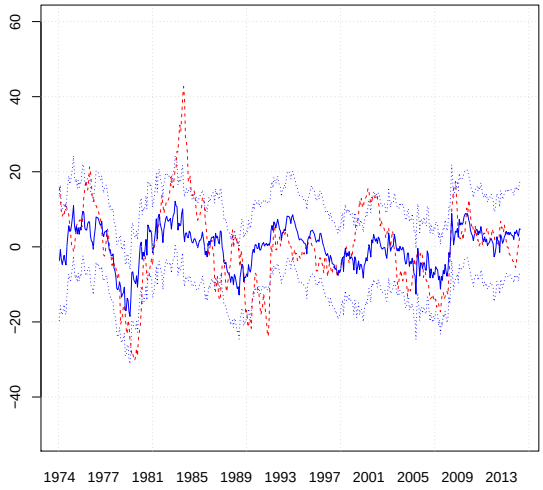
(a) Real DEM/USD



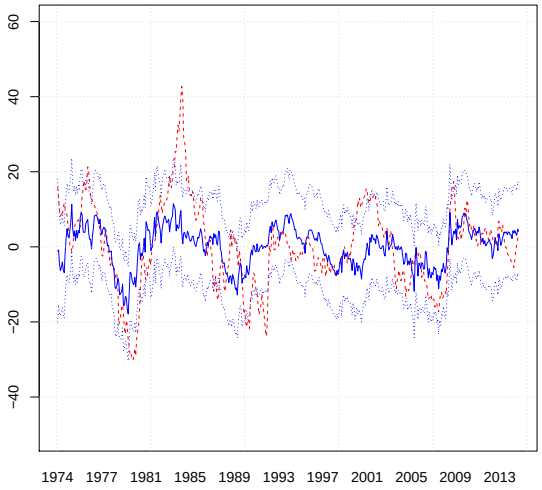
(b) Real DEM/USD (without SV)



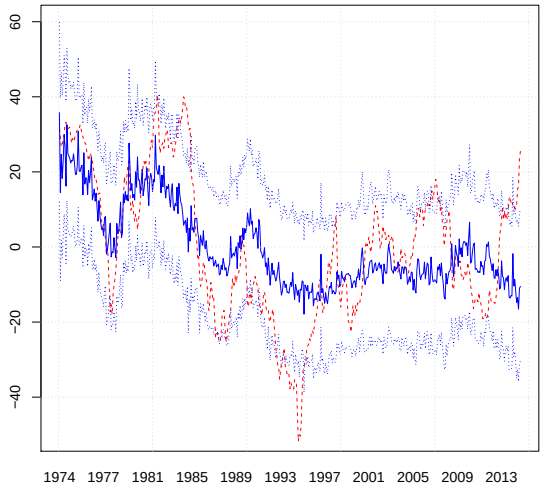
(c) Real GBP/USD



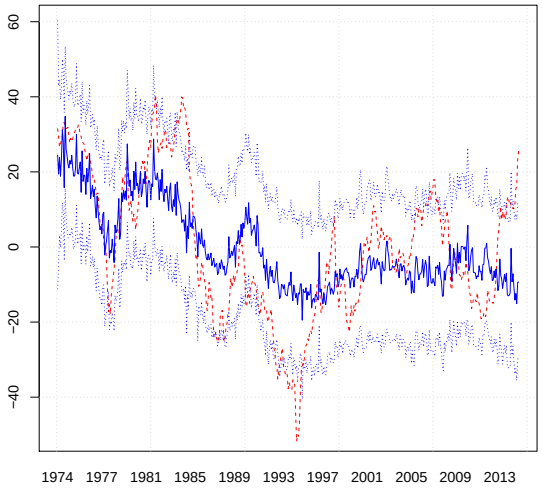
(d) Real GBP/USD (without SV)



(e) Real JPY/USD



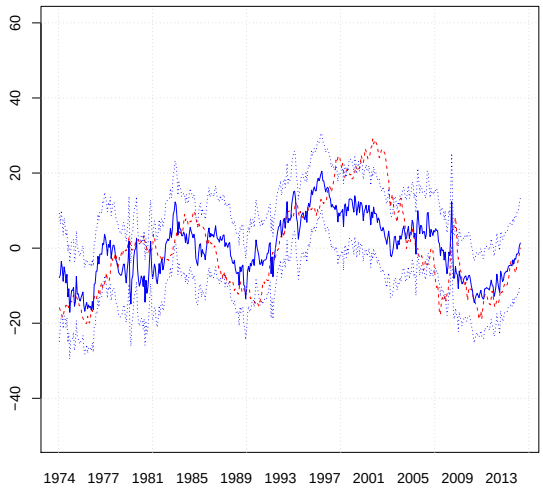
(f) Real JPY/USD (without SV)



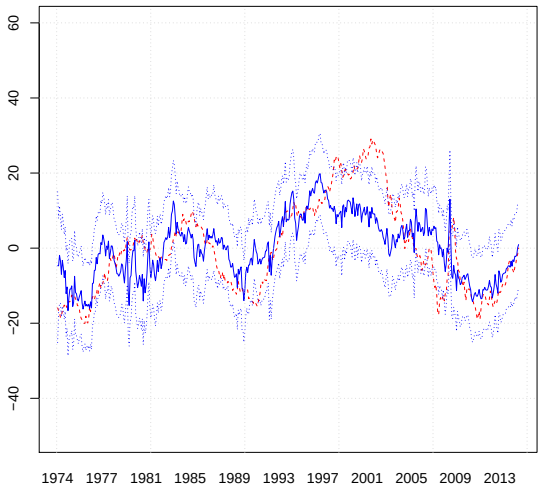
Notes: Actual real US Dollar exchange rates are given by dashed red lines (in logarithms times 100, centered around 0). The posterior median is given by the solid blue lines and the dashed blue lines correspond to 5th and 95th percentiles. The results are based on 15,000 posterior draws.

Figure 4 — Model predictions for small economies

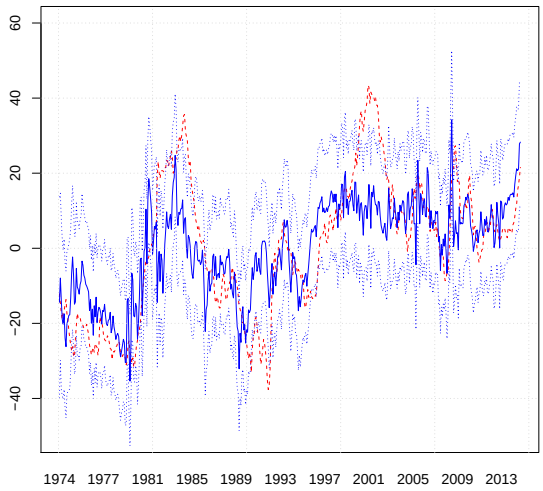
(a) Real CAD/USD



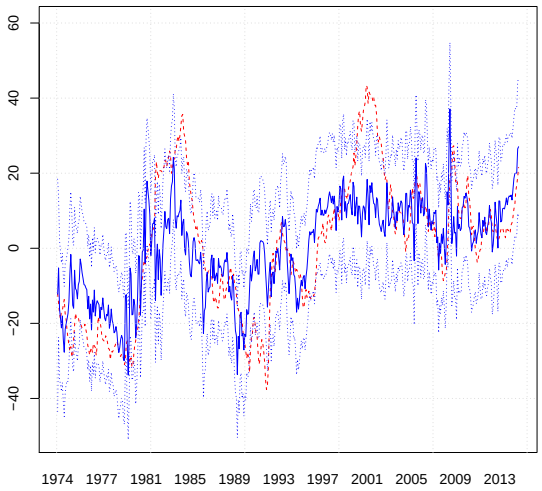
(b) Real CAD/USD (without SV)



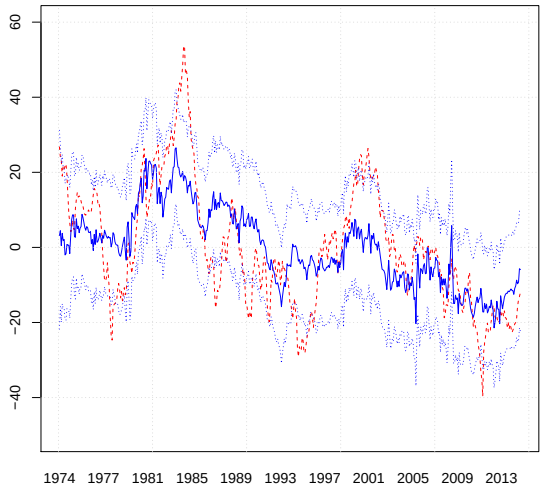
(c) Real SEK/USD



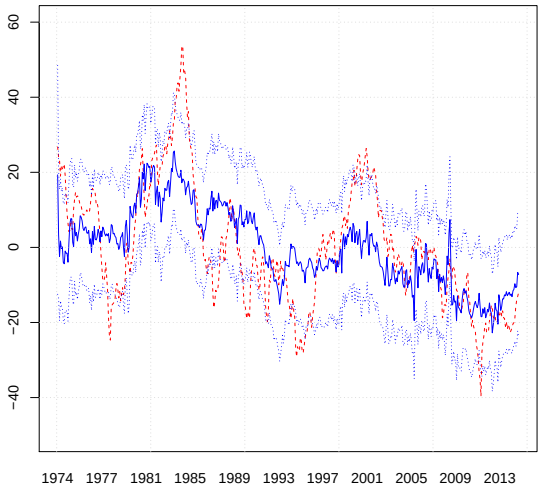
(d) Real SEK/USD (without SV)



(e) Real CHF/USD



(f) Real CHF/USD (without SV)



Notes: Actual real US Dollar exchange rates in dashed red lines (in logarithms times 100, centered around 0). The posterior median is given by the solid blue lines and the dashed blue lines correspond to 5th and 95th percentiles. The results are based on 15,000 posterior draws.

Appendix C.2 Model with HP-filtered trend

Table 4 — Correlation with actual exchange rate (HP-filter)

		(A) Real		(B) Nominal	
		Log-level	Log-change	Log-level	Log-change
DEM/USD	Benchmark	0.42	0.02	0.73	0.03
		[0.35, 0.49]	[−0.09, 0.12]	[0.70, 0.80]	[−0.08, 0.13]
	UC-SV	0.55	0.00	0.78	0.01
		[0.51, 0.59]	[−0.07, 0.07]	[0.76, 0.80]	[−0.06, 0.08]
GBP/USD	Benchmark	0.28	0.02	0.62	0.04
		[0.20, 0.37]	[−0.06, 0.11]	[0.58, 0.71]	[−0.04, 0.12]
	UC-SV	0.44	0.02	0.68	0.03
		[0.40, 0.49]	[−0.04, 0.09]	[0.65, 0.71]	[−0.03, 0.09]
JPY/USD	Benchmark	0.44	0.00	0.88	0.02
		[0.37, 0.50]	[−0.08, 0.09]	[0.87, 0.89]	[−0.06, 0.11]
	UC-SV	0.38	−0.01	0.88	0.00
		[0.33, 0.43]	[−0.07, 0.05]	[0.87, 0.89]	[−0.06, 0.06]
CAD/USD	Benchmark	0.56	0.04	0.66	0.06
		[0.51, 0.61]	[−0.05, 0.13]	[0.62, 0.60]	[−0.03, 0.14]
	UC-SV	0.45	0.06	0.57	0.07
		[0.41, 0.50]	[−0.00, 0.13]	[0.53, 0.60]	[0.01, 0.13]
SEK/USD	Benchmark	0.52	0.04	0.72	0.05
		[0.46, 0.57]	[−0.03, 0.12]	[0.69, 0.82]	[−0.02, 0.13]
	UC-SV	0.66	0.04	0.81	0.06
		[0.63, 0.69]	[−0.01, 0.10]	[0.79, 0.82]	[0.00, 0.12]
CHF/USD	Benchmark	0.47	0.03	0.86	0.04
		[0.40, 0.53]	[−0.05, 0.12]	[0.84, 0.86]	[−0.04, 0.13]
	UC-SV	0.43	0.03	0.85	0.04
		[0.38, 0.47]	[−0.03, 0.09]	[0.83, 0.86]	[−0.02, 0.10]

Notes: Posterior mean correlation with actual US Dollar exchange rate. 5th and 95th percentiles in brackets. The benchmark model does not take into account changes in the inflation and unemployment trends.

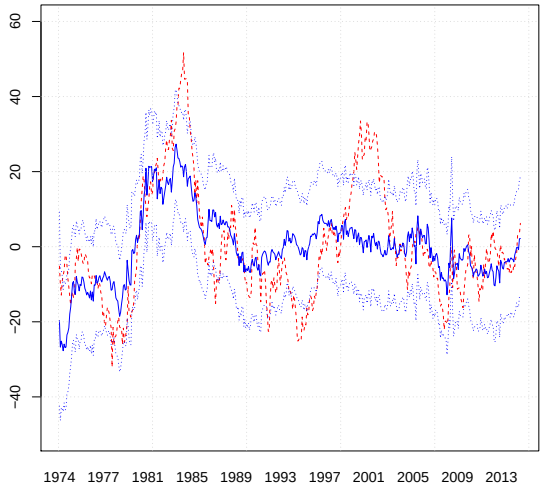
Table 5 — Autocorrelation real exchange rate (HP-filter)

		Log-level			Log-change		
		1st	2nd	3rd	1st	2nd	3rd
DEM/USD	Actual	0.98	0.96	0.93	0.01	0.04	0.04
	Benchmark	0.94	0.90	0.88	−0.14	−0.22	−0.03
	UC-SV	0.97	0.95	0.94	−0.32	−0.08	0.12
GBP/USD	Actual	0.97	0.94	0.90	0.33	0.02	0.05
	Benchmark	0.90	0.82	0.78	−0.13	−0.17	−0.06
	UC-SV	0.97	0.94	0.91	−0.03	−0.16	−0.05
JPY/USD	Actual	0.99	0.96	0.94	0.33	0.08	0.05
	Benchmark	0.90	0.89	0.87	−0.42	−0.01	−0.01
	UC-SV	0.94	0.92	0.91	−0.31	−0.16	0.02
CAD/USD	Actual	0.99	0.98	0.97	0.21	0.05	0.03
	Benchmark	0.95	0.91	0.89	−0.16	−0.12	−0.10
	UC-SV	0.93	0.86	0.82	−0.01	−0.17	−0.12
SEK/USD	Actual	0.99	0.97	0.95	0.36	0.04	0.05
	Benchmark	0.86	0.76	0.73	−0.12	−0.26	−0.10
	UC-SV	0.97	0.94	0.92	0.01	−0.17	−0.06
CHF/USD	Actual	0.98	0.96	0.93	0.27	0.03	0.02
	Benchmark	0.94	0.91	0.90	−0.18	−0.24	−0.04
	UC-SV	0.96	0.94	0.92	−0.13	−0.19	0.02

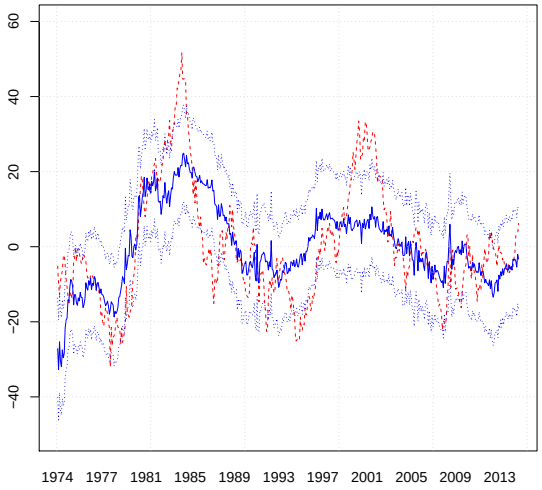
Notes: Sample autocorrelation function for the actual real US Dollar exchange rate and sample autocorrelation function for the posterior mean of the model predictions up to 3rd order. The benchmark model does not take into account changes in the inflation and unemployment trends.

Figure 5 — Model predictions for large economies

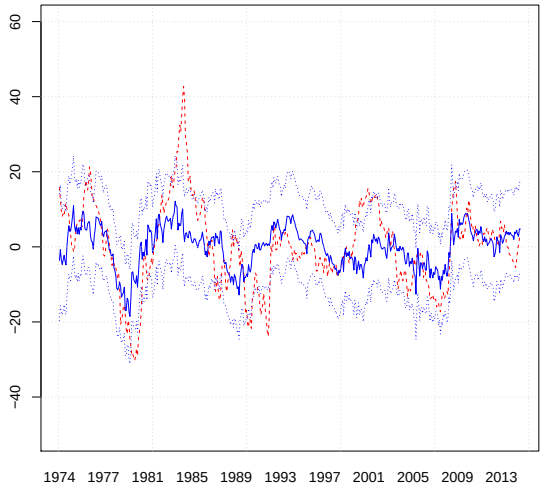
(a) Real DEM/USD



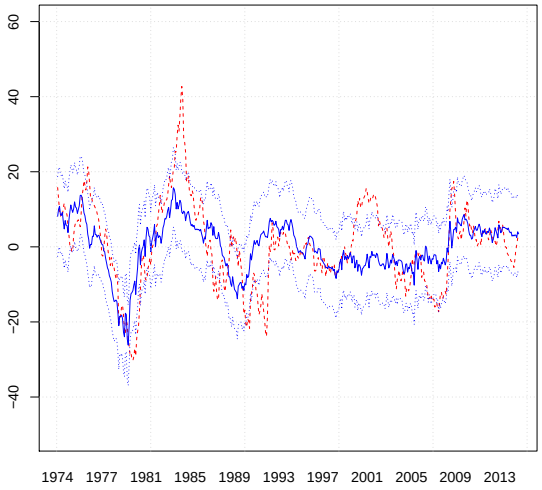
(b) Real DEM/USD (HP-filter)



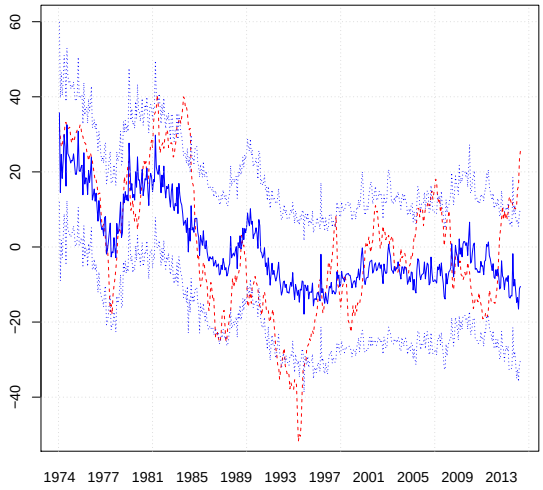
(c) Real GBP/USD



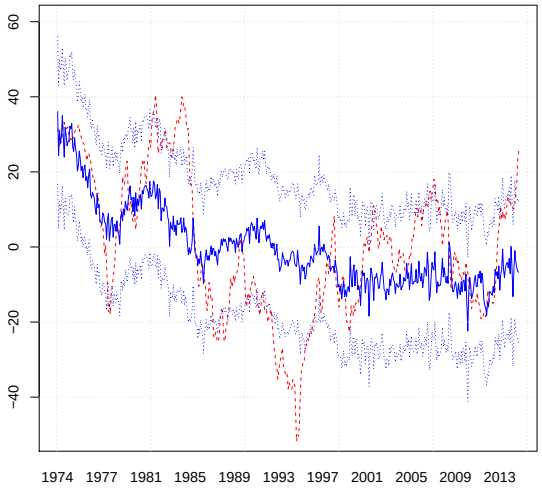
(d) Real GBP/USD (HP-filter)



(e) Real JPY/USD



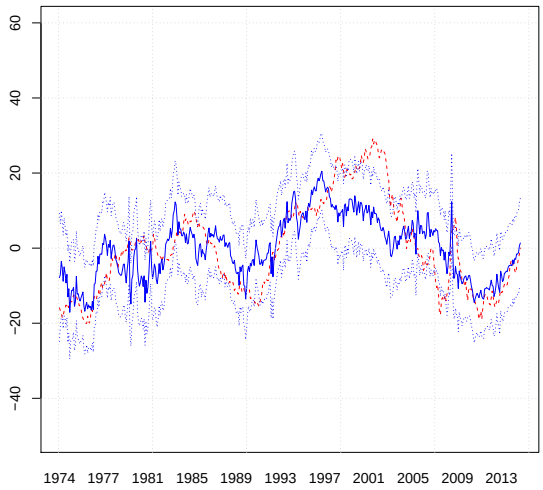
(f) Real JPY/USD (HP-filter)



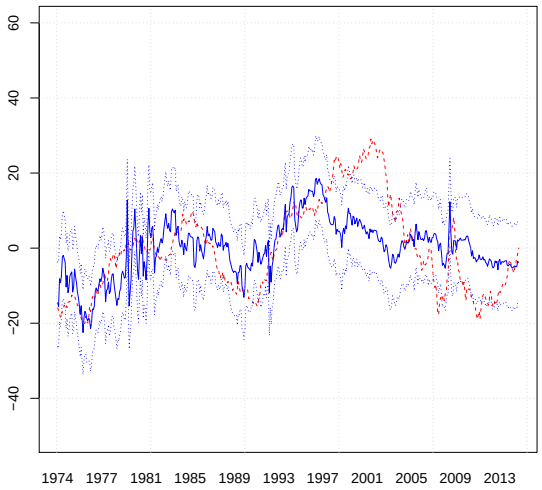
Notes: Actual real US Dollar exchange rates are given by dashed red lines (in logarithms times 100, centered around 0). The posterior median is given by the solid blue lines and the dashed blue lines correspond to 5th and 95th percentiles. The results are based on 15,000 posterior draws.

Figure 6 — Model predictions for small economies

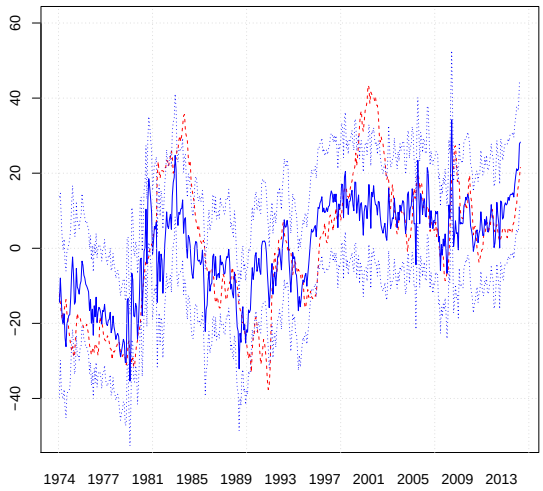
(a) Real CAD/USD



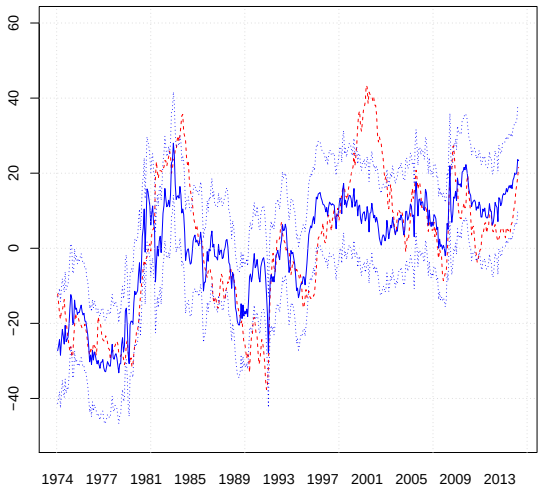
(b) Real CAD/USD (HP-filter)



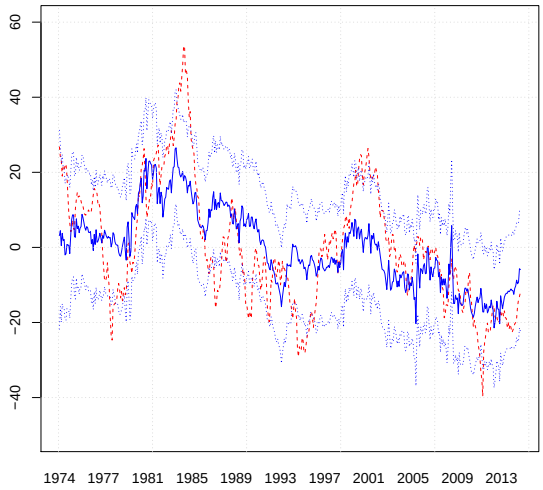
(c) Real SEK/USD



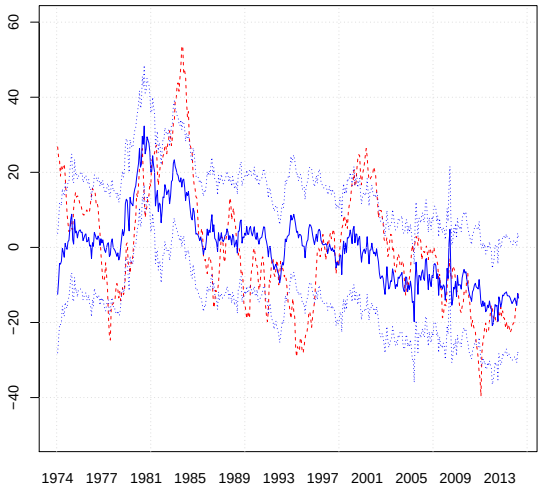
(d) Real SEK/USD (HP-filter)



(e) Real CHF/USD



(f) Real CHF/USD (HP-filter)



Notes: Actual real US Dollar exchange rates in dashed red lines (in logarithms times 100, centered around 0). The posterior median is given by the solid blue lines and the dashed blue lines correspond to 5th and 95th percentiles. The results are based on 15,000 posterior draws.

Appendix C.3 Model before introduction of Euro

Table 6 — Correlation with actual exchange rate (before introduction of Euro)

		(A) Real		(B) Nominal	
		Log-level	Log-change	Log-level	Log-change
DEM/USD	Benchmark	0.66	0.02	0.80	0.02
		[0.61, 0.71]	[−0.11, 0.15]	[0.76, 0.86]	[−0.11, 0.15]
	UC-SV	0.70	0.03	0.82	0.04
		[0.64, 0.77]	[−0.06, 0.13]	[0.79, 0.86]	[−0.05, 0.13]

Notes: Posterior mean correlation with actual US Dollar exchange rate. 5th and 95th percentiles in brackets. The benchmark model does not take into account changes in the inflation and unemployment trends.

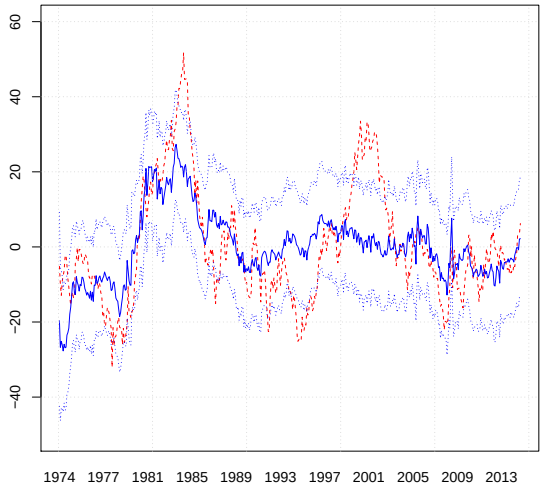
Table 7 — Autocorrelation real exchange rate (before introduction of Euro)

		(A) Real					
		Log-level			Log-change		
		1st	2nd	3rd	1st	2nd	3rd
DEM/USD	Actual	0.98	0.96	0.94	0.00	0.08	0.01
	Benchmark	0.96	0.93	0.91	−0.14	−0.13	0.00
	UC-SV	0.97	0.93	0.91	−0.04	−0.14	−0.04

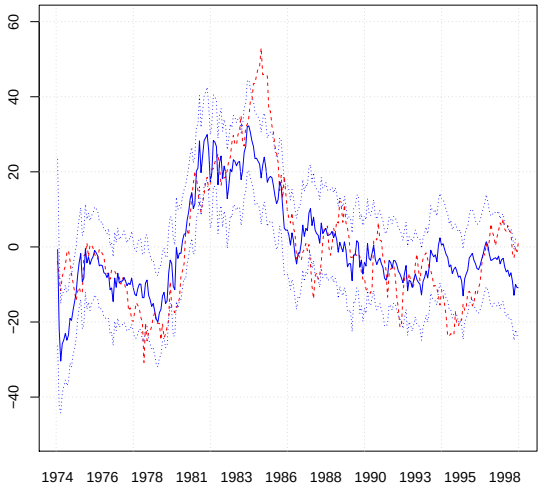
Notes: Sample autocorrelation function for the actual real US Dollar exchange rate and sample autocorrelation function for the posterior mean of the model predictions up to 3rd order. The benchmark model does not take into account changes in the inflation and unemployment trends.

Figure 7 — Model predictions for large economies

(a) Real DEM/USD



(b) Real DEM/USD (before euro introduction)



Notes: Actual real US Dollar exchange rates are given by dashed red lines (in logarithms times 100, centered around 0). The posterior median is given by the solid blue lines and the dashed blue lines correspond to 5th and 95th percentiles. The results are based on 15,000 posterior draws.

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