Term Premia and Inflation Uncertainty: Empirical Evidence from an International Panel Dataset

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Web Appendix of Supplementary Materials

Table App-1: Parameter Estimates for Affine Model

	Canada	CH	Germany	Norway	Sweden	UK	US	Australia	NZ	Japan
$[\mu]_1$	0.002	0.010	0.016	-0.004	0.003	0.017	0.001	0.014	0.009	0.001
	(0.012)	(0.007)	(0.009)	(0.012)	(0.011)	(0.017)	(0.014)	(0.013)	(0.009)	(0.003)
$[\mu]_2$	-0.006	-0.009	0.002	0.005	-0.005	0.006	-0.005	0.007	0.006	-0.001
	(0.004)	(0.002)	(0.004)	(0.005)	(0.004)	(0.007)	(0.004)	(0.005)	(0.004)	(0.001)
$[\mu]_3$	0.001	0.004	0.003	-0.004	-0.001	0.000	-0.001	0.003	-0.001	0.000
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)
$[\mu]_4$	0.331	-0.001	0.678	2.000	0.863	0.738	0.728	1.389	1.251	0.424
	(0.286)	(0.247)	(0.586)	(0.543)	(0.455)	(0.420)	(0.409)	(0.339)	(0.459)	(0.194)
$[\mu]_5$	0.612	0.864	0.593	1.244	0.688	2.427	0.800	0.335	0.284	0.126
	(0.348)	(0.273)	(0.265)	(0.409)	(0.358)	(0.581)	(0.447)	(0.366)	(0.213)	(0.121)
$[\Phi]_{11}$	0.968	0.908	0.854	0.970	0.947	0.931	0.944	0.928	0.962	0.952
	(0.034)	(0.065)	(0.059)	(0.077)	(0.044)	(0.055)	(0.049)	(0.043)	(0.049)	(0.042)
$[\Phi]_{21}$	0.019	0.072	-0.008	-0.013	-0.004	-0.010	0.005	-0.015	0.011	0.027
	(0.012)	(0.022)	(0.025)	(0.030)	(0.014)	(0.023)	(0.014)	(0.015)	(0.021)	(0.015)
$[\Phi]_{31}$	0.000	-0.031	-0.031	-0.028	0.007	-0.008	0.011	0.002	0.009	0.004
	(0.006)	(0.012)	(0.016)	(0.012)	(0.007)	(0.011)	(0.006)	(0.008)	(0.009)	(0.008)
$[\Phi]_{41}$	0.505	4.706	-4.154	0.647	-2.847	-1.684	-1.236	1.172	0.674	-8.029
	(0.844)	(2.181)	(3.876)	(3.408)	(1.762)	(1.373)	(1.406)	(1.124)	(2.450)	(2.792)
$[\Phi]_{51}$	-2.078	-9.656	-3.525	6.845	-3.172	-10.321	-2.754	-1.481	-1.900	-4.935
	(1.028)	(2.406)	(1.752)	(2.568)	(1.385)	(1.899)	(1.537)	(1.213)	(1.136)	(1.740)
$[\Phi]_{12}$	0.132	0.162	-0.105	0.093	0.401	-0.205	0.093	-0.164	-0.085	-0.146
	(0.159)	(0.226)	(0.124)	(0.411)	(0.256)	(0.117)	(0.146)	(0.193)	(0.171)	(0.139)
$[\Phi]_{22}$	0.806	0.640	0.899	0.538	0.777	0.884	0.884	0.799	0.776	0.882
	(0.058)	(0.075)	(0.052)	(0.159)	(0.084)	(0.048)	(0.044)	(0.067)	(0.074)	(0.050)
$[\Phi]_{32}$	-0.011	0.111	-0.008	0.004	-0.064	-0.036	-0.017	-0.023	0.022	0.004
	(0.029)	(0.042)	(0.033)	(0.063)	(0.042)	(0.023)	(0.018)	(0.034)	(0.032)	(0.026)
$[\Phi]_{42}$	-13.096	-9.360	4.845	35.772	-17.501	6.220	-6.610	5.338	4.098	-10.491
	(3.925)	(7.612)	(8.178)	(18.139)	(10.359)	(2.902)	(4.242)	(4.987)	(8.518)	(9.299)
$[\Phi]_{52}$	6.817	13.892	-9.205	-17.666	18.520	-7.677	-0.650	-7.713	-3.326	3.114
	(4.782)	(8.397)	(3.696)	(13.669)	(8.142)	(4.014)	(4.639)	(5.380)	(3.950)	(5.795)
$[\Phi]_{13}$	1.211	0.095	-0.819	1.297	-0.414	0.179	-0.137	-0.513	0.124	0.925
	(0.643)	(0.503)	(0.392)	(0.778)	(0.638)	(0.488)	(0.795)	(0.622)	(0.606)	(0.566)
$[\Phi]_{23}$	0.576	0.363	0.422	-0.039	0.413	0.677	1.096	0.516	0.666	0.526
	(0.235)	(0.167)	(0.164)	(0.301)	(0.209)	(0.202)	(0.236)	(0.215)	(0.260)	(0.203)
$[\Phi]_{33}$	0.348	0.573	0.473	0.558	0.673	0.688	0.598	0.339	0.246	0.360
	(0.116)	(0.092)	(0.104)	(0.119)	(0.105)	(0.098)	(0.097)	(0.111)	(0.114)	(0.104)

Table of parameter estimates (continued)

	Canada	CH	Germany	Norway	Sweden	UK	US	Australia	NZ	Japan
$[\Phi]_{43}$	12.035	27.855	17.974	20.119	7.173	-16.977	1.631	-6.742	-25.865	6.463
	(15.891)	(16.950)	(25.759)	(34.303)	(25.806)	(12.124)	(23.036)	(16.098)	(30.119)	(37.805)
$[\Phi]_{53}$	-2.054	-26.240	31.900	2.874	0.977	42.582	-37.021	-24.449	-13.317	-13.075
	(19.360)	(18.698)	(11.642)	(25.849)	(20.282)	(16.768)	(25.192)	(17.368)	(13.969)	(23.557)
$[\Phi]_{14}$	-0.004	-0.004	-0.007	0.007	-0.001	-0.005	-0.004	-0.005	-0.005	-0.002
	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
$[\Phi]_{24}$	0.001	0.002	-0.001	-0.001	0.001	-0.001	0.001	-0.001	-0.002	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
$[\Phi]_{34}$	0.000	-0.001	-0.001	0.001	0.000	0.000	0.000	-0.001	0.000	0.000
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
$[\Phi]_{44}$	0.939	0.885	0.857	0.085	0.791	0.860	0.940	0.732	0.776	0.935
	(0.057)	(0.064)	(0.136)	(0.170)	(0.099)	(0.087)	(0.079)	(0.065)	(0.073)	(0.079)
$[\Phi]_{54}$	0.006	-0.008	0.051	0.134	-0.027	-0.261	0.053	0.081	0.062	0.095
	(0.069)	(0.071)	(0.061)	(0.128)	(0.078)	(0.120)	(0.086)	(0.070)	(0.034)	(0.049)
$[\Phi]_{15}$	0.003	-0.002	-0.001	-0.005	-0.001	-0.002	0.003	0.000	0.002	0.002
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)
$[\Phi]_{25}$	0.001	0.004	0.000	-0.002	0.001	-0.001	0.001	-0.001	-0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
$[\Phi]_{35}$	-0.001	-0.002	-0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
$[\Phi]_{45}$	-0.080	0.102	-0.200	-0.064	-0.227	-0.162	-0.198	-0.189	-0.265	-0.605
	(0.077)	(0.103)	(0.188)	(0.198)	(0.152)	(0.095)	(0.093)	(0.074)	(0.145)	(0.165)
$[\Phi]_{55}$	0.720	0.505	0.678	0.271	0.622	0.288	0.672	0.796	0.812	0.522
	(0.094)	(0.113)	(0.085)	(0.149)	(0.120)	(0.131)	(0.102)	(0.080)	(0.067)	(0.103)
$[\Sigma]_{11}$	0.030	0.055	0.073	0.046	0.226	0.059	0.075	0.017	0.009	0.004
	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
$[\Sigma]_{21}$	0.010	-0.016	0.050	0.062	-0.146	0.008	0.009	0.006	0.009	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$[\Sigma]_{31}$	-0.009	-0.009	0.070	0.010	0.067	-0.012	0.016	-0.008	0.001	0.002
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$[\Sigma]_{41}$	-0.070	-0.078	-0.197	0.182	-0.248	-0.018	-0.129	-0.049	0.051	-0.024
	(0.011)	(0.007)	(0.013)	(0.020)	(0.019)	(0.009)	(0.012)	(0.012)	(0.019)	(0.010)
$[\Sigma]_{51}$	-0.042	-0.072	-0.034	-0.014	-0.130	-0.117	-0.096	-0.052	-0.033	-0.025
	(0.013)	(0.008)	(0.006)	(0.015)	(0.014)	(0.012)	(0.012)	(0.012)	(0.009)	(0.006)
$[\Sigma]_{22}$	0.005	0.006	0.038	0.088	0.097	0.002	0.002	0.011	0.010	0.016
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$[\Sigma]_{32}$	-0.001	0.003	0.053	0.009	-0.036	0.000	0.000	-0.001	-0.003	-0.005
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$[\Sigma]_{42}$	-0.034	0.011	-0.155	0.245	0.136	-0.018	-0.023	0.018	0.073	0.076
	(0.004)	(0.002)	(0.005)	(0.008)	(0.006)	(0.004)	(0.003)	(0.004)	(0.008)	(0.004)
$[\Sigma]_{52}$	0.012	0.037	-0.002	-0.051	0.112	-0.007	0.005	-0.056	-0.027	-0.044
	(0.005)	(0.003)	(0.002)	(0.006)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.002)

Table of parameter estimates (continued)

	Canada	CH	Germany	Norway	Sweden	UK	US	Australia	NZ	Japan
$[\Sigma]_{33}$	0.003	0.001	0.075	0.012	0.035	0.006	0.008	0.004	0.021	0.004
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$[\Sigma]_{43}$	0.013	0.012	-0.218	0.052	-0.124	-0.022	-0.013	0.031	-0.110	-0.052
	(0.002)	(0.001)	(0.003)	(0.003)	(0.003)	(0.002)	(0.001)	(0.002)	(0.004)	(0.002)
$[\Sigma]_{53}$	0.028	0.012	-0.003	0.067	0.023	0.041	-0.052	0.015	-0.038	-0.002
	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
$[\Sigma]_{44}$	0.228	0.199	0.641	0.751	0.441	0.229	0.278	0.282	0.911	0.673
	(0.359)	(0.331)	(1.152)	(1.244)	(0.981)	(0.301)	(0.447)	(0.417)	(1.319)	(0.969)
$[\Sigma]_{54}$	-0.040	-0.017	-0.027	0.029	-0.062	-0.107	0.060	-0.004	-0.001	-0.017
	(0.310)	(0.259)	(0.369)	(0.663)	(0.549)	(0.300)	(0.357)	(0.318)	(0.433)	(0.428)
$[\Sigma]_{55}$	0.365	0.258	0.154	0.483	0.323	0.325	0.332	0.325	0.183	0.255
	(0.533)	(0.403)	(0.235)	(0.706)	(0.606)	(0.576)	(0.535)	(0.485)	(0.284)	(0.376)
r^*	0.034	0.047	0.017	0.034	0.045	0.036	0.022	0.043	0.027	0.018
	(0.121)	(0.060)	(0.097)	(0.055)	(0.063)	(0.463)	(0.004)	(1.088)	(0.316)	(0.036)
$[\Lambda]_{11}$	-0.003	-0.006	-0.027	-0.002	-0.002	-0.010	-0.029	-0.002	-0.002	-0.011
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)	(0.001)
$[\Lambda]_{22}$	-0.122	-0.154	-0.062	-0.167	-0.100	-0.098	-0.076	-0.131	-0.158	-0.110
	(0.004)	(0.036)	(0.004)	(0.008)	(0.006)	(0.006)	(0.005)	(0.006)	(0.003)	(0.007)
$[\Lambda]_{33}$	-0.382	-0.189	-0.414	-0.295	-0.313	-0.414	-0.529	-0.305	-0.432	-0.233
	(0.013)	(0.043)	(0.013)	(0.015)	(0.013)	(0.014)	(0.023)	(0.012)	(0.009)	(0.014)

Notes: Parameter estimates for the affine term structure model. Standard errors are in parentheses.

Definitions of Alternative Affine Models

Model A1. This model has as the state vector the first three principal components of yields (for each country). This is the state vector under both P and Q measures. The state vector is observed, and estimation is by the method described in the text.

Model A2. Under the P measure, this model has the first three principal components of domestic yields and the first two principal components of yields in all countries as elements of the state vector. Under the Q measure, only the domestic yields are in the state vector. Thus the global factors are unspanned risk factors. The state vector is observed, and estimation is by the method described in the text.

Model A3. This model is similar to that estimated by Bernanke, Reinhart and Sack (2004). The elements of the state vector are short-term (three-month) interest rates, the exponentially-weighted moving average of quarterly inflation and GDP growth, and year-ahead forecasts of inflation and GDP growth from Consensus forecasts. The state vector is observed, and estimation is by the method described in the text.

Model A4. This is the model of Christensen, Diebold and Rudebusch (2009) in which the Nelson-Siegel level, slope and curvature factors are used as the state variables. This model can be cast in state space form (as shown by Christensen, Diebold and Rudebusch). Hence, assuming Gaussianity of the errors, it is estimated by maximum likelihood via the Kalman filter. In implementing this, the 3-month, 5-year and 10-year yields are treated as observed without error; all other yields are treated as observed with iid measurement error.

Table App-2 reports the fit of these different models. Table App-3 reports the Wald statistics testing the hypothesis that lags of global factors do not enter the equations for domestic yields. Then the estimated five-to-ten-year forward term premiums for these four alternative models are shown on the subsequent four pages of this appendix.

Table App-2: Fit of Affine Term Structure Models

Model	A1	A2	A3	A4
Canada	0.043	0.043	0.646	0.011
Switzerland	0.054	0.054	0.261	0.009
Germany	0.043	0.043	0.473	0.010
Norway	0.031	0.031	0.431	0.005
Sweden	0.043	0.043	0.436	0.007
UK	0.069	0.069	0.565	0.039
US	0.051	0.051	0.418	0.021
Australia	0.040	0.040	0.441	0.008
New Zealand	0.023	0.023	0.341	0.004
Japan	0.025	0.025	0.420	0.005

Notes: This table shows the root mean square fitting error (the square root of the average squared difference between actual yields and the fitted yields from the estimated affine term structure model) for each model and each country, in annualized percentage points.

Table App-3: Relevance of Macro Factors in model A2 under the P-measure

Canada	1563.2^{***}
Switzerland	886.5^{***}
Germany	659.6^{***}
Norway	1870.4^{***}
Sweden	1873.3^{***}
UK	1551.6^{***}
US	901.9^{***}
Australia	1421.4^{***}
New Zealand	1141.8^{***}
Japan	625.8^{***}

Notes: This table reports the Wald statistic testing the hypothesis that all elements of the matrix Φ that represent the effects of macroeconomic variables onto domestic yields are jointly equal to zero. One, two and three asterisks denote significance at the 10, 5, and 1 percent levels.

Figure A1. Five-to-ten year forward term premium estimates in model A1

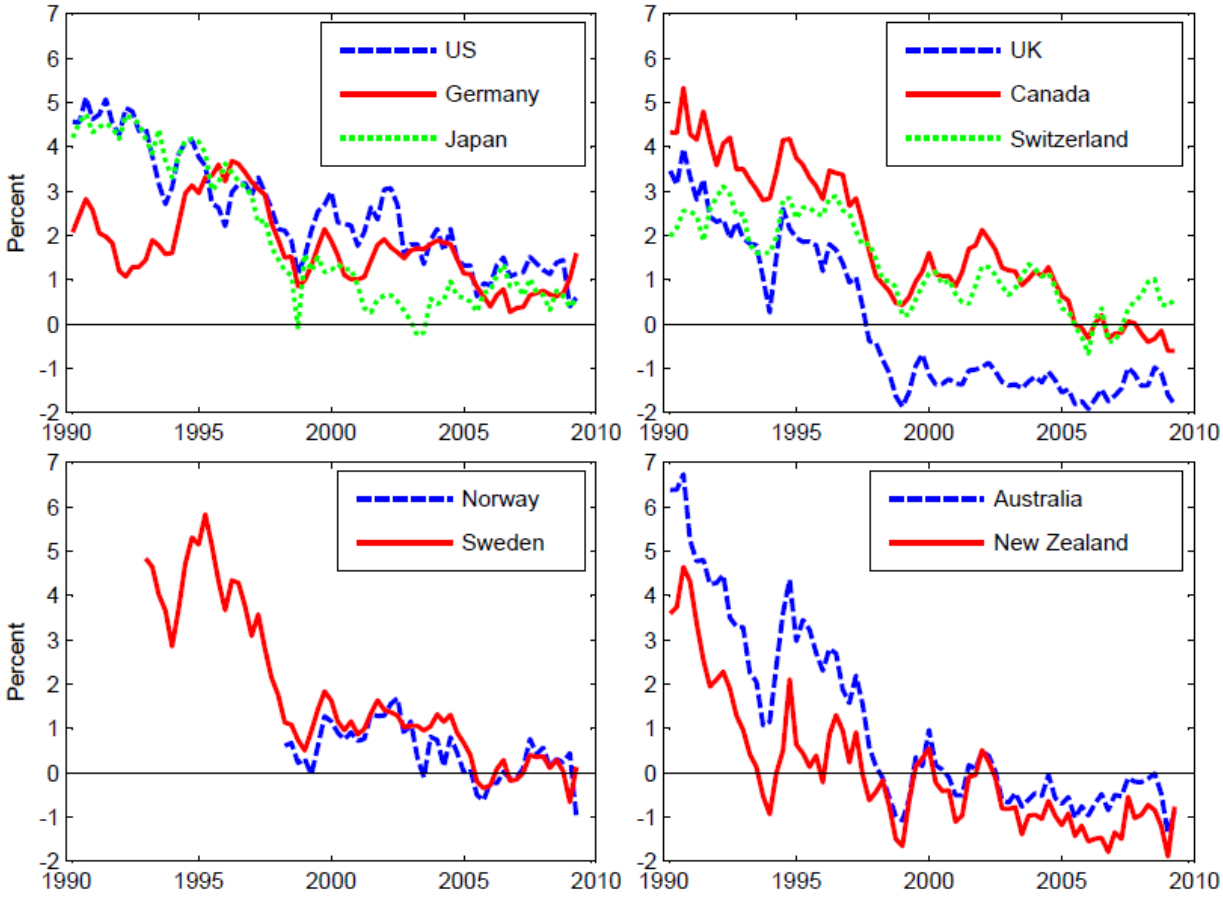


Figure A2. Five-to-ten year forward term premium estimates in model A2

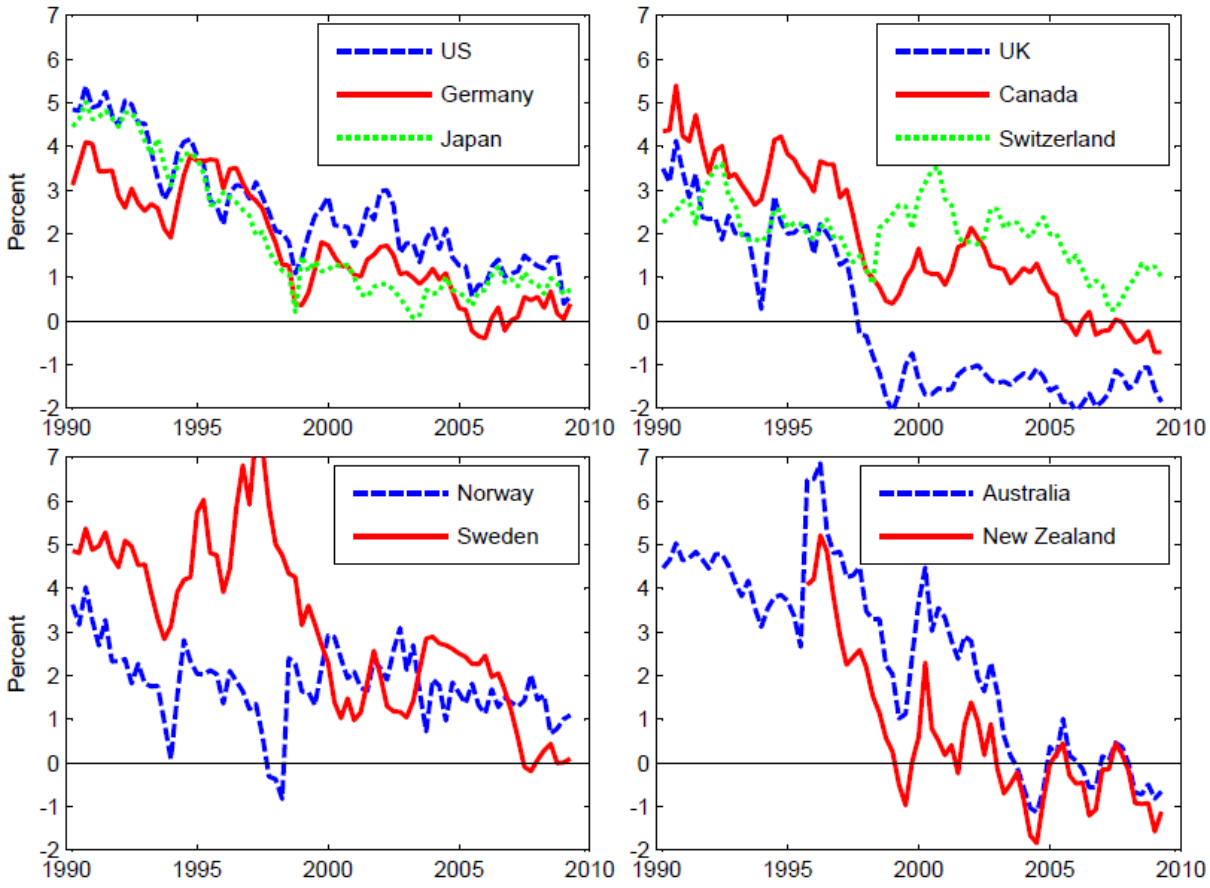


Figure A3. Five-to-ten year forward term premium estimates in model A3

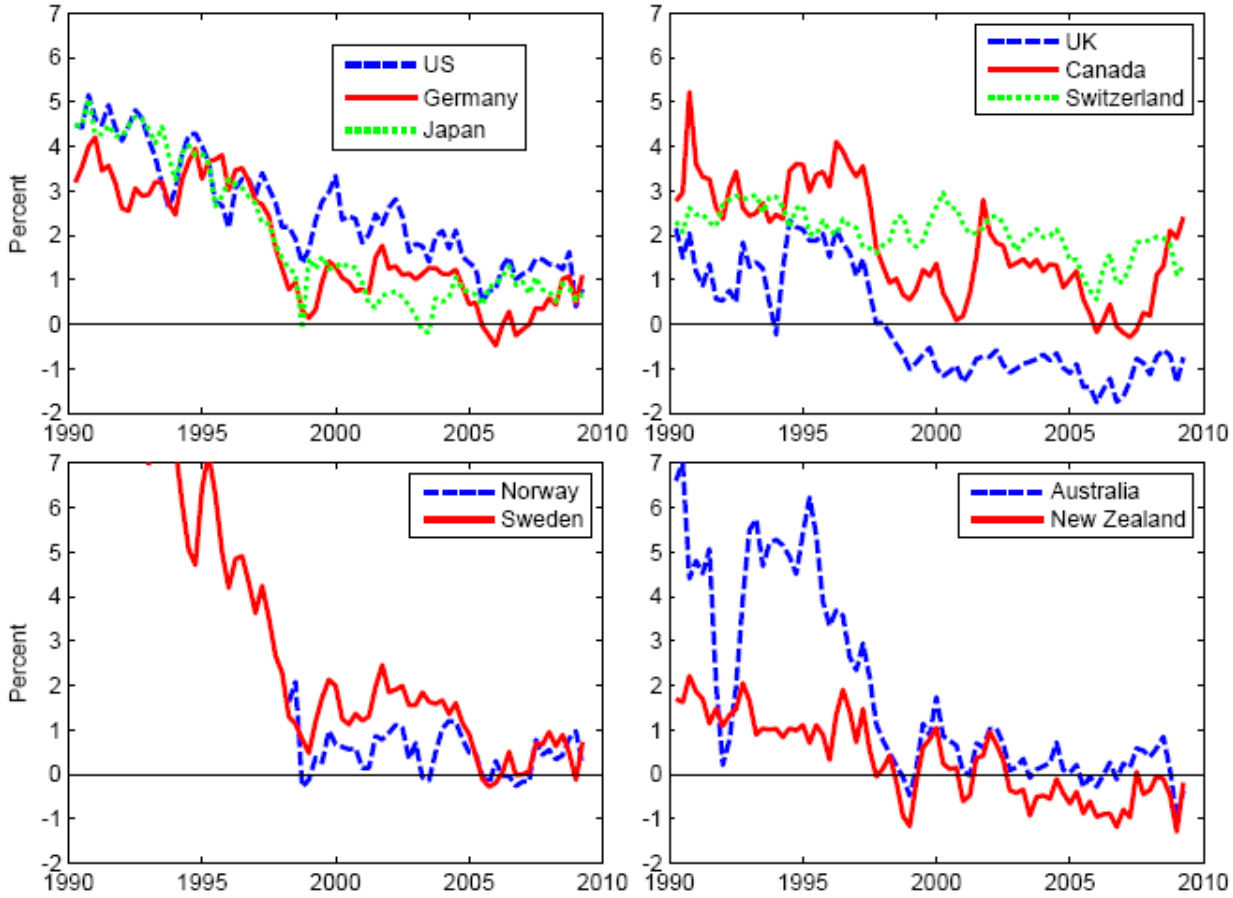
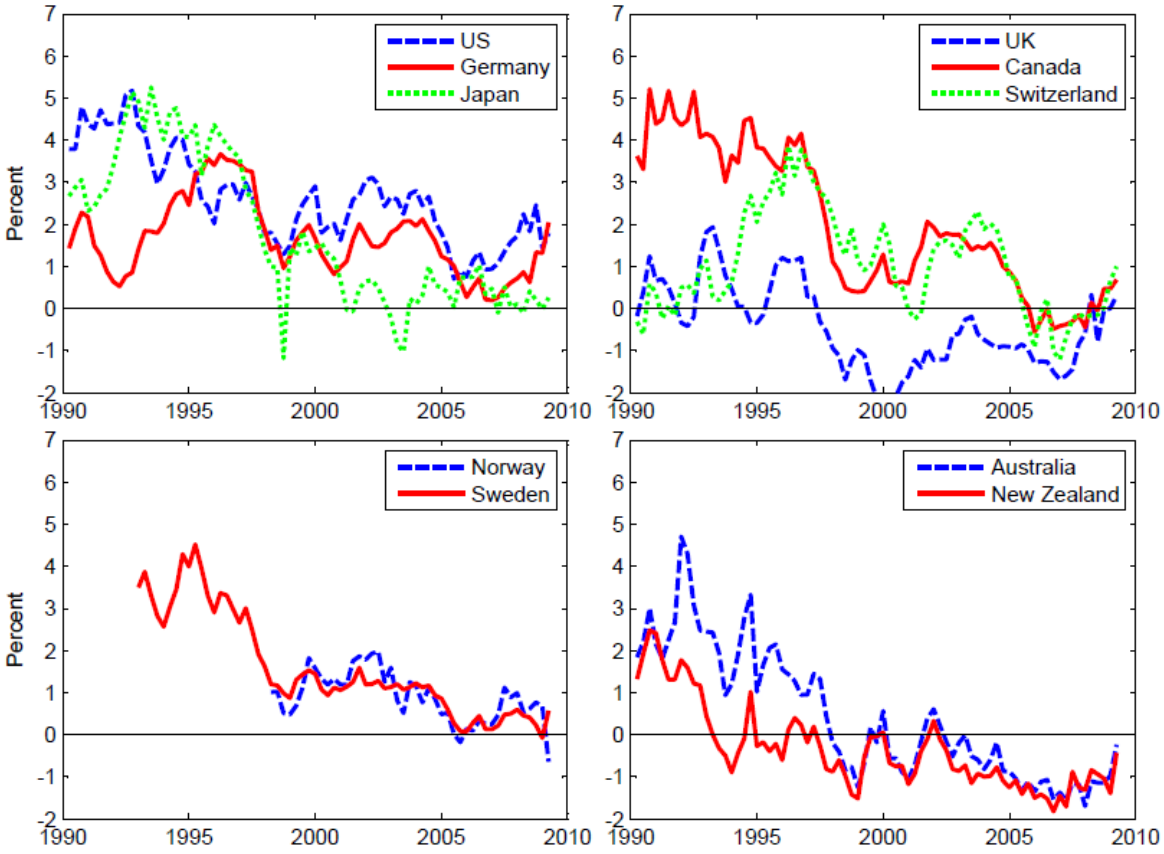


Figure A4. Five-to-ten year forward term premium estimates in model A4



Alternative Measures of Inflation Uncertainty

Finally, the appendix shows two alternative measures of inflation uncertainty:

1. Survey forecast variability. The two-year rolling standard deviation of changes to the year-ahead median survey inflation forecast.

2. Rolling realized inflation volatility. This is the ten-year rolling standard deviation of actual quarterly inflation. Note however that this conflates volatility of the transient part of inflation with volatility of the permanent part (while the unobserved components stochastic volatility model of Stock and Watson (2007) separates these two).

The final two pages of the appendix plot these inflation uncertainty measures for all ten countries in the sample.

Figure I1: Two-year rolling standard deviation of year-ahead inflation forecasts

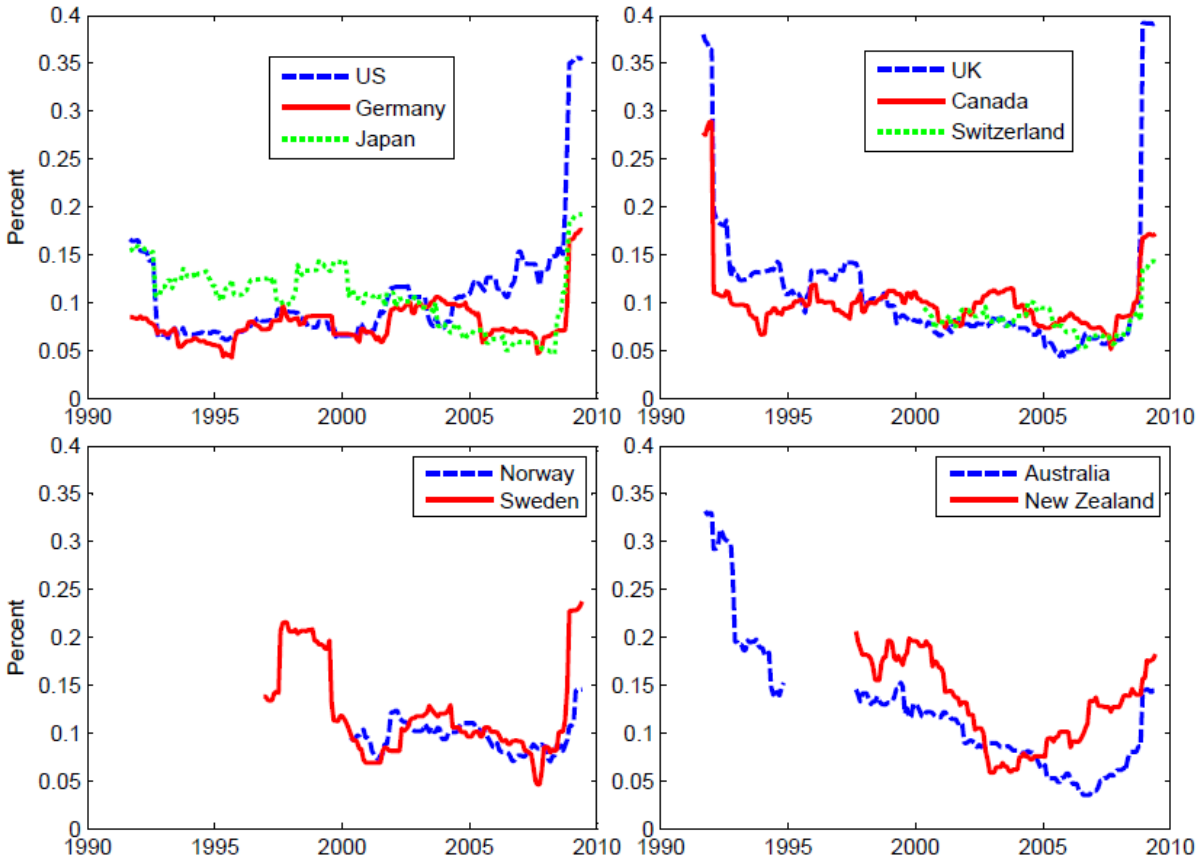


Figure I2: Ten-year rolling realized volatility of quarterly inflation

