International Disaster Risk

- Supplementary Online Appendix -

NOT FOR PUBLICATION

A Data

A.1 Macro-economic Data

Our macroeconomic series come from the quarterly database of the OECD. Our sample window starts in 1970:I and ends in 2009:IV. The following countries are in our sample: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Data for Germany only starts in 1990:I.

We use the following series: real GDP Y, real private consumption expenditures C, employment N, employment in the business sector N_b, real investment (e.g the gross fixed capital formation) I, real private investment in the non-residential sector I_b, a productivity index Y/N, defined as real GDP divided by total employment, and a balance of payment measure of the current account CA/Y, expressed as a fraction of GDP.

These series are not available at the quarterly frequency for Austria, Greece, Hungary, and Turkey.

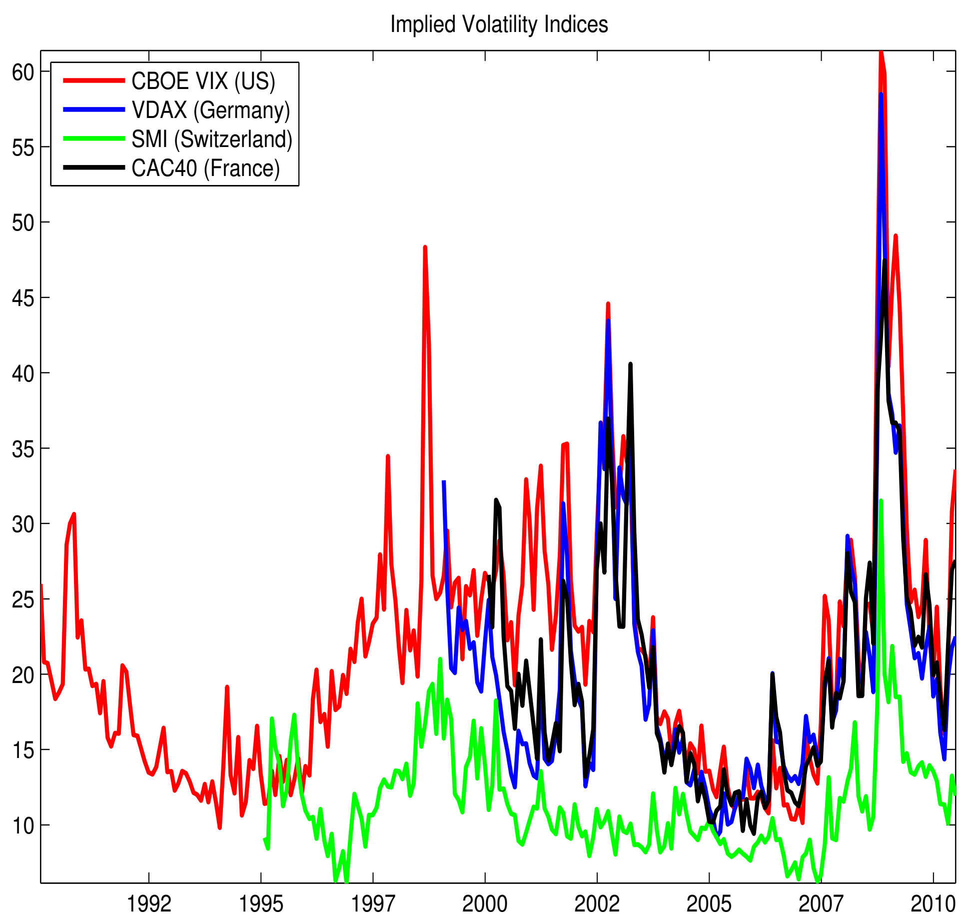
A.2 Financial Data

Our financial series come from the monthly databases of the IMF and MSCI. From the IMF database, we extract nominal exchange rates s in foreign currency per US dollar (when s increases, the US dollar appreciates), nominal short term interest rates i, and consumer price indices. We use Treasury Bill rates whenever available, and money market rates otherwise. From the MSCI database, we extract stock market indices R^m. We compute real interest rates as nominal interest rates minus expected inflation, which we approximate using 12-month differences in log price indices. The maximum sample period is 1970:1–2009:12, but sample windows vary across countries.

There is no monthly CPI series for Australia and New Zealand. There is no MSCI index for Iceland, Luxembourg, and Slovakia.

Figure 7 reports time-series of option-implied market volatility in the US, Germany, Switzerland and France. We use the following option-based indices: VIX (United States), VDAX (Germany), SMI (Switzerland), CAC (France), BEL (Belgium), AEX (Netherlands), currencies (US Dollar to UK pound, US Dollar to Japanese yen), along with a US bond index (1 month).

Figure 7: Option-Implied Stock Market Volatility



This figure plots time-series of option-implied stock market volatility in the US, Germany, Switzerland and France.

B VARs

Following Bloom (2009), our VARs contain the following variables in order: market returns, volatility, and the macroeconomic series under study. We obtain similar results when we add consumer price indices and short-term interest rates. To obtain stationary series, we use differences in log variables. To account for seasonality, we use 12 lags for monthly series when computing these log differences. For variables expressed in percentages (market returns and interest rates), we do not take logs. We obtain similar results when using HP filters on levels.

We use 12 lags in the estimation of our monthly VARs. We use a simple Cholesky decomposition to obtain structural residuals. Volatility series are ordered after market returns to focus on a volatility shock that is orthogonal to market returns. Standard errors on impulse response functions are obtained by bootstrapping 500 times the VAR residuals. Standard errors correspond to 5 and 95 percentiles.

Figures 8 and 9 report the impulse response functions of industrial production and unemployment rates to a shock on average volatility. Each panel focuses on a different country. Dotted lines correspond to standard errors.

C Portfolios

Following Lustig and Verdelhan (2007), we sort countries into portfolios based on interest rates in order to study carry trade returns. At the end of each period t, we allocate all currencies in the sample to five portfolios on the basis of their nominal interest rates observed at the end of period t. Portfolios are re-balanced at the end of every month. They are ranked from low to high interests rates; portfolio 1 contains the currencies with the lowest interest rates, and portfolio 5 contains the currencies with the highest interest rates. We compute the log currency excess return rx_{t+1}^j for portfolio j by taking the average of the log currency excess returns in each portfolio j. We do not take into account transaction costs.

The total number of currencies in our portfolios varies over time. We have a total of 10 countries at the beginning of the sample in 1971 and 17 at the end in 2009. We only include currencies for which we have interest rates and exchange rates in the current and subsequent period. The maximum number of currencies attained during the sample is 27; the launch of the euro accounts for the subsequent decrease in the sample size.

Table 1 reports summary statistics on our currency portfolios from the perspective of a US investor. For each portfolio j, we report average changes in the spot rate Δs^j, the interest rate differences $i^j - i^{US}$, the log currency excess returns $rx^j = -\Delta s^j + i^j - i^{US}$. We report log returns because these are the sum of interest rate differences and the change in spot rates. We also report log currency excess returns on carry trades or high-minus-low investment strategies that go long in portfolio $j = 2, 3 \ldots, 5$, and short in the first portfolio: $rx^j_{net} - rx^1_{net}$. All exchange rates and returns are reported in US dollars and the moments of returns are annualized: we multiply the mean of the monthly data by 12 and the standard deviation by $\sqrt{12}$. The Sharpe ratio is the ratio of the annualized mean to the annualized standard deviation.

The first panel reports the average rate of depreciation for all currencies in portfolio j. According to the standard uncovered interest rate parity (UIP) condition, the average rate of depreciation $E_T\left(\Delta s^j\right)$ of currencies in portfolio j should equal the average forward discount on these currencies $E_T\left(i^j - i^{US}\right)$, reported in the second panel. Instead, currencies in the first portfolio trade at an average interest rate difference of -212 basis points, but they appreciate on average only by almost 165 basis points over this sample. This adds up to a log currency excess return of minus 47 basis points on average, which is reported in the third panel. Currencies in the last portfolio trade at an average interest rate difference of 1472 basis points but they depreciate only by 862 basis points on average. This adds up to a log currency excess return of 610 basis points on average.

A large body of empirical work starting with Hansen and Hodrick (1980) and Fama (1984) reports violations of UIP in the time series. However, these results are different because we only consider whether a currency's interest rate is currently high, not whether it is higher than usual.

The fourth panel reports average log currency excess returns. Note that the first column reports *minus* the actual log excess return for the first portfolio, because the investor is short in these currencies. The corresponding Sharpe ratio on this first portfolio is minus 0.04. The return on the fifth portfolio is equal to 610 basis points. The corresponding Sharpe ratio on the last portfolio is 0.54.

The fifth panel reports returns on zero-cost strategies that go long in the high interest rate portfolios and short in the low interest rate portfolio. The spread between the returns on the first and the last portfolio is 657 basis points. This high-minus-low strategy delivers a Sharpe ratio of 0.64. Again, these excess returns do not take into account transaction costs. However, Lustig et al. (2009) show that such excess returns remain highly significant even after taking into account bid-ask spreads.

The sixth panel reports volatility betas obtained as slope coefficients in regressions of currency excess returns on a constant and a measure of aggregate volatility on G7 equity markets. High interest rate currencies depreciate when aggregate volatility is high whereas low interest rate currencies appreciate.

The seventh panel reports average real interest rates for each portfolio. Even if we sort countries on nominal interest rates, we obtain a clear monotonic cross-section of real interest rates.[21] This result helps justifying our focus on a real business cycle model without money.

The eighth panel reports average inflation rates. We also obtain a clear monotonic cross-section of inflation rates.

The last two panels focus on equity returns expressed in foreign currencies. The eighth panel reports average equity excess returns. High interest rate countries tend to offer low equity excess returns to local investors, while low interest rate countries boast higher equity excess returns. Verdelhan (2010) reports similar results. Note, however, that we do not obtain here a perfectly monotonically decreasing cross-section. The median portfolio offers a slightly higher excess return than the first one.

The last panel reports equity return volatilities. The higher the interest rate, the more volatile the equity returns.

D Computational Method

The method used to solve the model is exactly as in Gourio (2009). Given parameter values, we apply this method to solve for each country's allocation. We then obtain the stochastic discount

[21] Real interest rates are obtained as differences between nominal interest rates and expected inflation, where the latter is estimated using the previous twelve-month log difference in consumer price indices.

Table 7: Business Cycles: Summary Statistics – OECD Countries

	$\sigma(\Delta y)$	$\sigma(\Delta c)/\sigma(\Delta y)$	$\sigma(\Delta n)/\sigma(\Delta y)$	$\sigma(\Delta n_b)/\sigma(\Delta y)$	$\sigma(\Delta i)/\sigma(\Delta y)$	$\sigma(\Delta i_b)/\sigma(\Delta y)$	$\sigma(\Delta(y-n))$	$\sigma(\Delta(ca-y))$
Australia	1.96	0.76	0.59	0.79	2.87	3.94	2.08	1.79
Belgium	1.26	0.90	0.45	0.57	3.20	3.70	–	2.86
Canada	1.65	0.99	0.71	0.93	2.75	3.54	1.29	2.25
Czech Republic	2.35	1.16	0.36	0.78	2.98	–	2.35	2.76
Denmark	1.92	1.20	0.52	–	3.86	5.08	–	–
Finland	2.89	0.89	0.55	0.59	2.83	4.27	2.68	4.42
France	1.21	1.03	1.00	0.53	2.22	2.83	1.02	1.33
Germany	1.66	1.17	0.40	–	2.67	3.06	1.60	3.25
Iceland	4.02	1.16	0.68	0.83	3.54	–	5.07	9.00
Ireland	2.63	0.87	0.63	0.71	3.17	6.33	2.18	4.77
Japan	2.19	1.07	0.35	0.38	2.03	2.77	2.09	1.48
Luxembourg	3.31	0.60	0.25	0.35	4.16	–	3.30	–
Mexico	2.81	1.19	–	–	3.34	–	–	2.41
Netherlands	2.41	0.85	0.30	0.59	4.07	4.36	2.47	2.63
New Zealand	5.54	0.63	0.25	–	1.92	3.20	4.46	3.17
Norway	2.59	0.98	0.54	–	4.47	6.18	2.72	8.49
Poland	2.45	0.95	0.71	0.83	3.63	–	–	2.20
Portugal	1.91	1.07	0.93	–	2.61	–	–	4.67
Slovakia	4.26	0.92	0.34	–	2.92	–	3.92	4.47
South Korea	3.11	1.27	0.47	0.49	4.15	4.09	2.72	4.43
Spain	1.57	0.97	1.02	–	2.87	–	–	3.61
Sweden	2.14	0.89	0.52	0.60	2.40	3.80	2.06	3.76
Switzerland	1.38	0.67	0.97	–	3.25	–	–	4.14
United Kingdom	1.93	1.13	0.43	0.56	2.85	5.83	1.77	1.76
United States	1.71	0.80	0.62	0.74	2.63	2.95	1.28	1.97
Average (excl. US)	2.46	0.97	0.56	0.64	3.12	4.20	2.58	3.62

Notes: This table reports, for each country, the standard deviation of log real GDP y, along with the standard deviations of log real private consumption expenditures c, log employment n, log employment in the business sector n_b, log real investment (e.g gross fixed capital formation) i, log real private investment in the non-residential sector i_b. All these volatility measures are reported in percentage of the standard deviation of y. The table also reports the standard deviation of a log productivity index $y-n$, defined as real GDP divided by total employment, as well as the standard deviation of the current account $ca-y$, expressed as a fraction of GDP. The maximum sample period is 1970.I–2009.IV, but sample windows vary across countries. Data come from the OECD database, available on Datastream.

Table 8: Business Cycles: Within-Country Correlations – OECD Countries

	$Corr(\Delta c, \Delta y)$	$Corr(\Delta n, \Delta y)$	$Corr(\Delta n_b, \Delta y)$	$Corr(\Delta i, \Delta y)$	$Corr(\Delta i_b, \Delta y)$
Australia	0.42	0.18	0.16	0.46	0.30
Belgium	0.70	0.38	0.36	0.54	0.37
Canada	0.61	0.63	0.55	0.51	0.40
Czech Republic	0.16	0.36	0.35	0.41	–
Denmark	0.52	0.37	–	0.61	0.50
Finland	0.56	0.35	0.38	0.59	0.53
France	0.61	0.06	0.51	0.69	0.65
Germany	0.33	0.29	–	0.74	0.71
Iceland	0.40	-0.09	-0.11	0.58	–
Ireland	0.49	0.58	0.57	0.66	0.51
Japan	0.73	0.31	0.29	0.75	0.55
Luxembourg	0.29	0.12	0.15	0.26	–
Mexico	0.78	–	–	0.74	–
Netherlands	0.39	0.24	0.20	0.59	0.45
New Zealand	0.46	0.19	–	0.37	0.26
Norway	0.24	0.17	–	-0.03	-0.04
Poland	0.02	0.15	0.14	0.54	–
Portugal	0.57	0.09	–	0.73	–
Slovakia	0.37	0.48	–	0.33	–
South Korea	0.72	0.48	0.54	0.50	0.54
Spain	0.68	0.56	–	0.68	–
Sweden	0.49	0.33	0.28	0.38	0.34
Switzerland	0.64	0.44	–	0.52	–
United Kingdom	0.67	0.40	0.39	0.38	0.18
United States	0.65	0.60	0.67	0.77	0.63
Average (excl. US)	0.49	0.31	0.32	0.52	0.42

Notes: This table reports, for each country, the correlation between the log real GDP y and log real private consumption expenditures c, log employment n, log employment in the business sector n_b, log real investment (e.g gross fixed capital formation) i, log real private investment in the non-residential sector i_b. The maximum sample period is 1970.I–2009.IV, but sample windows vary across countries. Data come from the OECD database, available on Datastream.

Table 9: Business Cycles: Cross-Country Correlations – OECD Countries

	$(\Delta y, \Delta y^{US})$	$(\Delta c, \Delta c^{US})$	$(\Delta n, \Delta n^{US})$	$(\Delta n_b, \Delta n_b^{US})$	$(\Delta i, \Delta i^{US})$	$(\Delta i_b, \Delta i_b^{US})$	$(\Delta(y-n), \Delta(y-n)^{US})$	$(\Delta(ca-y), \Delta(ca-y)^{US})$
Australia	0.32	0.16	0.22	0.24	0.16	0.16	0.26	0.59
Belgium	0.32	0.19	0.23	0.22	0.05	0.14	–	-0.28
Canada	0.50	0.35	0.60	0.57	0.39	0.41	0.13	-0.63
Czech Republic	0.28	-0.05	0.24	0.13	0.16	–	0.20	0.31
Denmark	0.32	0.31	0.42	–	0.22	0.13	–	–
Finland	0.07	0.09	0.20	0.19	0.08	0.07	-0.11	-0.65
France	0.35	0.22	0.01	0.24	0.28	0.33	0.09	-0.06
Germany	0.51	0.12	0.18	–	0.33	0.52	0.24	-0.75
Iceland	0.12	0.16	0.14	0.13	0.32	–	-0.03	0.43
Ireland	0.23	0.39	0.33	0.35	0.42	0.36	0.05	-0.21
Japan	0.29	0.26	0.21	0.23	0.27	0.27	0.05	-0.76
Luxembourg	0.16	0.04	0.03	0.15	0.01	–	-0.01	–
Mexico	0.26	0.08	–	–	0.14	–	–	-0.42
Netherlands	0.27	0.10	0.25	0.31	0.14	0.12	0.11	-0.54
New Zealand	0.30	0.08	0.16	–	0.20	0.20	0.13	0.23
Norway	0.25	0.10	0.16	–	0.07	0.06	0.06	-0.71
Poland	0.33	0.03	0.11	0.02	0.27	–	–	0.30
Portugal	0.24	0.00	-0.03	–	0.23	–	–	0.34
Slovakia	0.36	0.02	0.25	–	0.05	–	0.24	0.36
South Korea	0.16	0.17	0.20	0.16	0.06	0.11	0.06	-0.54
Spain	0.19	0.31	0.26	–	0.21	–	–	0.40
Sweden	0.26	0.20	0.15	0.09	0.28	0.32	0.21	-0.80
Switzerland	0.27	0.22	0.12	–	0.26	–	–	-0.72
United Kingdom	0.35	0.28	0.43	0.51	0.25	0.20	0.16	0.41
United States	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Average (excl. US)	0.28	0.16	0.21	0.24	0.20	0.23	0.11	-0.17

Notes: This table reports, for each country, the correlation between the log real GDP y, log real private consumption expenditures c, log employment n, log employment in the business sector n_b, log real investment (e.g gross fixed capital formation) i, log real private investment in the non-residential sector i_b, log productivity index $y-n$, defined as real GDP divided by total employment, $ca-y$, expressed as a fraction of GDP, and their counterparts in the US. The maximum sample period is 1970.I–2009.IV, but sample windows vary across countries. Data come from the OECD database, available on Datastream.

Table 10: Asset Prices: Summary Statistics – OECD Countries

	$\sigma(\Delta s)$	$\bar{i}$	$\sigma(i)$	$\overline{R^m}$	$\sigma(R^m)$	$\sigma(\Delta q)$	$\bar{r}$	$\sigma(r)$	$\overline{R^m - i}$	$\sigma(R^m - i)$	SR	$(\Delta q, \Delta c - \Delta c^{\star})$
Australia	10.66	8.84	3.88	9.87	20.35	–	–	–	0.82	21.55	0.04	–
Austria	11.01	6.25	2.14	6.64	20.75	11.09	2.12	2.31	1.12	19.01	0.06	–
Belgium	11.17	6.71	3.32	9.65	18.68	11.27	2.76	2.74	2.92	18.68	0.16	0.14
Canada	6.12	6.90	3.85	9.84	17.27	6.25	2.50	2.80	2.93	17.34	0.17	0.06
Czech Republic	11.91	5.74	3.73	11.56	26.58	11.75	0.95	2.25	9.21	25.94	0.36	0.07
Denmark	10.71	13.18	3.96	11.41	18.05	10.88	7.09	1.78	4.18	19.14	0.22	0.20
Finland	10.00	7.85	4.83	9.54	32.62	10.21	3.98	3.18	3.74	32.72	0.11	0.06
France	10.88	7.25	3.83	9.84	20.52	10.87	2.47	2.65	2.49	20.56	0.12	0.05
Germany	11.19	4.89	2.16	7.23	20.11	10.98	1.86	0.90	4.89	19.91	0.25	-0.22
Greece	10.02	11.98	7.65	12.55	33.67	11.72	3.08	3.60	1.52	33.56	0.05	–
Hungary	10.09	16.65	8.99	18.49	35.02	10.79	3.61	3.31	5.16	34.80	0.15	–
Iceland	13.75	12.11	7.23	–	–	13.49	4.48	4.56	–	–	–	0.25
Ireland	10.22	10.36	3.94	3.26	22.31	8.69	2.86	1.10	8.56	20.11	0.43	-0.26
Japan	10.90	2.92	2.37	5.84	18.72	11.19	-0.09	3.06	2.90	18.69	0.15	0.02
Luxembourg	11.17	6.03	2.68	–	–	11.25	3.76	1.77	–	–	–	0.07
Mexico	19.88	28.74	26.19	27.85	27.97	15.61	6.84	14.55	7.26	27.48	0.26	-0.01
Netherlands	11.14	6.29	2.84	9.95	18.48	11.37	2.23	3.69	7.01	17.37	0.40	0.13
New Zealand	11.59	8.90	3.91	4.66	19.46	–	–	–	-3.03	19.57	-0.15	–
Norway	10.00	8.26	3.92	10.80	25.87	10.09	3.25	3.58	1.16	26.20	0.04	0.10
Poland	23.35	15.75	11.27	18.45	43.27	20.41	4.11	3.33	4.46	43.22	0.10	0.05
Portugal	10.75	11.50	4.12	4.99	21.07	11.83	2.93	2.57	-0.03	21.51	-0.00	0.26
Slovakia	9.74	5.66	1.97	–	–	10.07	-0.08	2.46	–	–	–	-0.01
South Korea	11.36	10.87	5.78	8.75	31.82	11.34	4.61	3.96	0.01	32.01	0.00	-0.04
Spain	10.50	8.66	5.30	11.23	20.85	10.63	2.79	2.95	6.33	21.86	0.29	0.27
Sweden	10.70	7.36	3.93	13.85	22.83	10.88	2.15	3.39	6.18	22.89	0.27	0.18
Switzerland	11.99	3.25	2.46	7.62	16.99	12.08	1.10	1.49	6.18	16.91	0.37	0.11
Turkey	23.03	52.24	28.35	44.66	52.15	24.51	17.97	26.12	-8.86	54.28	-0.16	–
United Kingdom	10.06	7.96	3.51	11.06	19.69	10.37	1.70	3.86	3.08	19.66	0.16	0.12
United States	0.00	5.69	3.02	9.11	15.68	0.00	1.28	2.28	3.40	15.69	0.22	–
Average (excl. US)	11.92	10.82	6.00	11.98	25.00	11.91	3.50	4.15	3.21	25.00	0.15	0.07

Notes: This table reports, for each country, the standard deviation of changes in nominal exchange rates $\sigma(\Delta s)$, the average $\bar{i}$ and standard deviation $\sigma(i)$ of nominal Treasury Bill rates, the average $\overline{R^m}$ and standard deviation $\sigma(R^m)$ of MSCI stock market returns. The table also reports the following sets of moments for real variables: the standard deviation of changes in real exchange rates $\sigma(\Delta q)$, the average $\bar{r}$ and standard deviation $\sigma(r)$ of nominal Treasury Bill rates, the average $\overline{R^m - i}$, standard deviation $\sigma(R^m - i)$, and Sharpe ratios SR of MSCI stock market excess returns. The last column reports the correlation $(\Delta q, \Delta c - \Delta c^{\star}$ between real changes in exchange rates and relative consumption growth at quarterly frequency. Averages and standard deviations are annualized (e.g multiplied by 12 and $\sqrt{12}$ respectively) and reported in percentages. Data are monthly (except for consumption). The maximum sample period is 1970:1–2009:12, but sample windows vary across countries. Data come from the IMF and MSCI databases, available on Datastream.

Table 11: Volatility Indices: Principal Components

% Var. explained by Factors	1	2	3	4
Realized Vol, 27 countries	40.99	16.49	8.17	6.28
Realized Vol, 15 countries	42.95	9.10	7.55	5.94
Implied Vol, 9 series	90.19	7.12	1.32	0.67

Notes: This table reports the fraction of total variances explained by the first four principal components of return volatilities. We consider three samples. The first sample comprises all OECD countries for which we have MSCI equity returns at daily frequency. We build monthly volatility series by computing standard deviations of daily equity returns over each calendar month. Countries in this sample are all the countries in Table 10 except Iceland, Luxembourg, and Slovakia. The second sample focuses on OECD countries for which we have such volatility data for all our time-window. Countries in this sample are: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, and United States. The third sample uses option-implied volatilities on equity indices VIX (United States), VDAX (Germany), SMI (Switzerland), CAC (France), BEL (Belgium), AEX (Netherlands), currencies (US Dollar to UK pound, US Dollar to Japanese yen), along with a US bond index (1 month). Monthly Data. Realized equity return volatilities in 27 or 15 OECD countries, 1/1970–12/2009. Implied Volatilities on bond, equity and currency returns, 1/1995–12/2009

Table 12: Principal Components - Countries Sorted on Nominal Interest Rates

Portfolio/Components	1	2	3	4	5
1	0.47	0.54	0.68	0.14	0.13
2	0.47	0.25	−0.30	−0.56	−0.56
3	0.45	0.00	−0.43	−0.16	0.77
4	0.46	−0.15	−0.30	0.77	−0.28
5	0.38	−0.79	0.42	−0.23	−0.03
$Var(\%)$	80.17	8.71	4.24	3.54	3.33

Notes: This table reports, for each portfolio j (row), the factor loadings on each principal component (column) of changes in exchange rates. The last line of the table reports the percentage of the total variance explained by each principal component. The portfolios are constructed by sorting currencies into five groups at time t based on short-term nominal interest rates at the end of period $t-1$. The first portfolio contains currencies with the lowest interest rates. The last portfolio contains currencies with the highest interest rates. Data are monthly. We focus on OECD countries. The sample starts in January 1971 and ends in December 2009.

factor for each country, then compute asset prices in each country and finally the exchange rate as the ratio of the stochastic discount factors.

Specifically, the Bellman equation for each country is

$$\begin{aligned}
W(K,z,p) &= \max_{C,I,N} \left\{ \left(C^{\upsilon}(1-N)^{1-\upsilon}\right)^{1-\gamma} + \beta \left(E_{p',z',x'} W(K',z',p')^{\frac{1-\theta}{1-\gamma}} \right)^{\frac{1-\gamma}{1-\theta}} \right\}, \\
s.t. &: \ C + I \leq z^{1-\alpha} K^{\alpha} N^{1-\alpha}, \\
K' &= \left((1-\delta)K + \phi\left(\frac{I}{K}\right) K \right) (1 - x' b_k), \\
\log z' &= \log z + \mu + \sigma\varepsilon' + x' \log(1 - b_{tfp}).
\end{aligned}$$

This can be simplified as follows: write $W(K,z,p) = z^{\upsilon(1-\gamma)} g(k,p)$ with

$$\begin{aligned}
g(k,p) &= \max_{c,i,N} \left\{ \begin{array}{c} c^{\upsilon(1-\gamma)}(1-N)^{(1-\upsilon)(1-\gamma)} \\ +\beta e^{\mu\upsilon(1-\gamma)} \left(E_{p',\varepsilon',x'} e^{\sigma\varepsilon'\upsilon(1-\theta)} (1 - x' b_{tfp})^{\upsilon(1-\theta)} g(k',p')^{\frac{1-\theta}{1-\gamma}} \right)^{\frac{1-\gamma}{1-\theta}} \end{array} \right\}, \\
s.t. &: \ c + i = k^{\alpha} N^{1-\alpha}, \\
k' &= \frac{(1 - x' b_k)\left((1-\delta)k + \phi\left(\frac{i}{k}\right) k\right)}{e^{\mu+\sigma\varepsilon'}(1 - x' b_{tfp})}.
\end{aligned}$$

Because we take a power $\frac{1}{1-\gamma}$ of the value function, the max needs to be transformed in a min if $\gamma > 1$.

This Bellman equation can then be easily solved by discretizing i and k. (See Gourio (2009) for details.) Given g, we have the value (utility) function $V(K,z,p) = W(K,z,p)^{\frac{1}{1-\gamma}} = z^{\upsilon} g(k,p)^{\frac{1}{1-\gamma}}$. We also obtain the policy functions $C = zc(k,p)$, $I = zi(k,p)$, $N = N(k,p)$, and the output policy function $Y = zk^{\alpha} N(k,p)^{1-\alpha}$. Because these policy functions are defined on a discrete grid, we use interpolation in the simulations and impulse responses to obtain more accurate results. (Linear or spline interpolations yield nearly the same results.)

We next obtain the stochastic discount factor, which is given by the standard formula:

$$M_{t,t+1} = \beta \left(\frac{C_{t+1}}{C_t}\right)^{\upsilon(1-\gamma)-1} \left(\frac{1-N_{t+1}}{1-N_t}\right)^{(1-\upsilon)(1-\gamma)} \left(\frac{V_{t+1}}{E_t\left(V_{t+1}^{1-\theta}\right)^{\frac{1}{1-\theta}}} \right)^{\gamma-\theta},$$

and hence the SDF between two states $s = (k, p)$ and $s' = (k', p')$ is:

$$\begin{aligned} M(s, s', \varepsilon', x') &= \beta \left(\frac{z' c(k', p')}{z c(k, p)} \right)^{\upsilon(1-\gamma)-1} \left(\frac{1 - N(k', p')}{1 - N(k, p)} \right)^{(1-\upsilon)(1-\gamma)} \left(\frac{z'^{\upsilon} g(k', p')^{\frac{1}{1-\gamma}}}{E_{z',p',x'} \left(z'^{\upsilon(1-\theta)} g(k', p')^{\frac{1-\theta}{1-\gamma}} \right)^{\frac{1}{1-\theta}}} \right)^{\gamma-\theta} \\ &= \beta \left(\frac{z'}{z} \right)^{(\gamma-\theta)\upsilon + \upsilon(1-\gamma)-1} \left(\frac{c(k', p')}{c(k, p)} \right)^{\upsilon(1-\gamma)-1} \times ... \\ & ... \left(\frac{1 - N(k', p')}{1 - N(k, p)} \right)^{(1-\upsilon)(1-\gamma)} \left(\frac{g(k', p')^{\frac{1}{1-\gamma}}}{E_{z',p',x'} \left(\left(\frac{z'}{z}\right)^{\upsilon(1-\theta)} g(k', p')^{\frac{1-\theta}{1-\gamma}} \right)^{\frac{1}{1-\theta}}} \right)^{\gamma-\theta} . \end{aligned}$$

Computing the expectation of this discount factor gives us the risk-free rate, $R_f(k, p)$. The equity is simply a claim to the stream $\{D_t\}$, with $D_t = Y_t^{\lambda}$. Let P_t denote its price, which satisfies the standard recursion:

$$P_t = E_t \left(M_{t,t+1} \left(P_{t+1} + D_{t+1} \right) \right).$$

Note that D_t can be written as $D_t = z_t^{\lambda} d(k_t, p_t)$. Hence, we can rewrite the firm value recursion as: $P_t = z_t^{\lambda} f(k_t, p_t)$, with

$$f(k, p) = E_{s'|s} \left(M(s, s') \times \left(\frac{z'}{z} \right)^{\lambda} \left(d(k', p') + f(k', p') \right) \right), \tag{D.1}$$

which can be solved simply by iterating starting with an initial guess $f(k, p) = 0$.

We solve using exactly the same method for the other country, then simulate the two countries given that disasters (and hence disaster risk) is perfectly correlated across countries, and given the assumed correlation of ε_t and $\varepsilon_t^{\star}$. The exchange rate satisfies

$$\frac{Q_{t+1}}{Q_t} = \frac{M_{t+1}^{\star}}{M_{t+1}},$$

where a higher Q corresponds to a depreciation of the home currency. The initial value of Q is set to 1, which is immaterial for our purposes.

To obtain the model statistics, we simulate 100 samples of length 50,000, starting at the nonstochastic steady-state levels of capital in each country, and cut off the first 1,000 periods. We use such long samples because some statistics suffer from small sample bias, see the discussion in the paper. We simulate samples with or without disasters, see the discussion in the paper.

The Matlab(c) programs are available on the author's web pages.

E Tables for the Robustness section

Table 13: Business Cycle Statistics — Robustness

	Standard Deviations								Cross-country Correlations			
	$\sigma(\Delta c)$	$\sigma(\Delta i)$	$\sigma(\Delta n)$	$\sigma(\Delta y)$	$\sigma(\Delta c^\star)$	$\sigma(\Delta i^\star)$	$\sigma(\Delta n^\star)$	$\sigma(\Delta y^\star)$	$(\Delta c, \Delta c^\star)$	$(\Delta i, \Delta i^\star)$	$(\Delta n, \Delta n^\star)$	$(\Delta y, \Delta y^\star)$
Benchmark	0.54	2.13	0.38	0.74	0.51	1.74	0.29	0.72	32.85	59.07	78.02	25.08
RBC	0.48	1.33	0.17	0.71	0.48	1.33	0.17	0.70	20.00	20.00	19.95	20.01
Small sample Benchmark	0.54	2.10	0.37	0.74	0.51	1.74	0.29	0.72	31.94	53.22	70.98	24.84
Small sample RBC	0.47	1.32	0.17	0.70	0.47	1.33	0.17	0.70	19.88	19.82	19.75	19.85
Sample with Disasters	2.66	3.28	0.38	2.68	2.11	2.63	0.29	2.15	96.63	82.31	77.84	92.84
Defaultable debt	0.54	2.14	0.39	0.74	0.51	1.74	0.29	0.72	32.94	59.24	78.14	25.13
Constant probability	0.48	1.35	0.17	0.71	0.47	1.35	0.17	0.71	19.98	19.94	19.89	19.97
Low risk aversion	0.49	1.57	0.25	0.71	0.49	1.48	0.22	0.71	24.58	38.11	57.13	21.69
Low IES	0.66	2.30	0.52	0.74	0.58	1.72	0.34	0.69	40.10	76.81	95.04	30.91
Lower TFP vol. in home	0.45	1.95	0.37	0.59	0.81	2.49	0.37	1.19	28.26	46.78	65.18	23.23
High correlation of TFP	0.54	2.13	0.38	0.74	0.51	1.73	0.29	0.72	49.32	68.62	83.02	43.64

Notes: This table reports the standard deviations of log differences in consumption, investment, labor and output, along with the cross-country correlation of these variables. The table is constructed by simulating the model, assuming disasters are actually realized. We consider three variants of the model: (1) our benchmark model with time-varying risk of disaster, where the domestic country is more risky (restated for convenience); (2) a long sample which includes disaster realizations.

Table 14: Financial statistics — Robustness

	Averages				Standard Deviations				Cross-country Corr.	
	$E(r^e - r^f)$	$E(r^f)$	$E(r^{e,\star} - r^{f,\star})$	$E(r^{f,\star})$	$\sigma(r^e)$	$\sigma(r^f)$	$\sigma(r^{e,\star})$	$\sigma(r^{f,\star})$	$(r^e, r^{e,\star})$	$(r^f, r^{f,\star})$
Benchmark	1.82	0.32	0.88	0.51	8.03	1.25	4.50	0.81	0.94	1.00
RBC	0.04	0.81	0.04	0.81	1.47	0.04	1.47	0.04	0.20	0.20
Small sample Benchmark	1.84	0.31	0.89	0.51	7.78	1.01	4.37	0.64	0.91	0.99
Small sample RBC	0.04	0.81	0.04	0.81	1.46	0.04	1.47	0.04	0.20	0.21
Sample with Disasters	1.56	0.32	0.67	0.52	8.57	1.25	5.30	0.80	0.93	1.00
Defaultable debt	1.58	0.56	0.73	0.67	8.07	0.65	4.52	0.41	0.94	0.99
Constant probability	0.95	0.30	0.61	0.50	1.47	0.04	1.47	0.04	0.20	0.20
Low risk aversion	0.34	0.65	0.27	0.69	2.16	0.53	1.97	0.41	0.59	0.99
Low IES	1.60	0.35	0.79	0.55	6.65	1.27	3.66	0.86	0.92	1.00
Lower TFP vol. in home	1.80	0.33	0.94	0.50	7.95	1.24	4.89	0.80	0.87	0.99
High correlation of TFP	1.81	0.32	0.88	0.52	8.01	1.24	4.49	0.80	0.95	1.00

Notes: This table reports the averages and standard deviations of log equity returns and log risk-free rates, along with the cross-country correlation of these variables. The table is constructed by simulating the model, assuming disasters are actually realized. We consider two variants of the model: (1) our benchmark model with time-varying risk of disaster, where the domestic country is more risky (restated for convenience); (2) a long sample which includes disaster realizations

Table 15: Real Exchange Rates — Robustness

	$E(\Delta q)$	$\sigma(\Delta q)$	$(\Delta q, r^e - r^{e,\star})$	$(\Delta q, r^f - r^{f,\star})$	$(\Delta q, \Delta y - \Delta y^\star)$	$(\Delta q, \Delta c - \Delta c^\star)$
Benchmark	0.89	6.21	98.76	-24.86	57.19	39.76
RBC	0.05	3.17	99.96	1.77	99.95	99.47
Small sample Benchmark	0.90	6.15	99.10	-26.94	59.93	43.47
Small sample RBC	0.04	3.16	99.96	-3.97	99.96	99.59
Sample with Disasters	0.77	6.31	98.09	-18.91	59.61	44.23
Defaultable debt	0.89	6.22	98.73	-24.37	57.14	39.64
Constant probability	0.27	3.16	99.96	1.67	99.95	99.47
Low risk aversion	0.00	0.54	98.18	5.47	99.55	99.98
Low IES	0.81	5.94	99.19	-23.95	38.65	67.16
Lower TFP vol. in home	0.88	6.81	98.82	-22.33	66.39	54.59
High correlation of TFP	0.87	5.99	98.73	-25.74	53.10	32.50

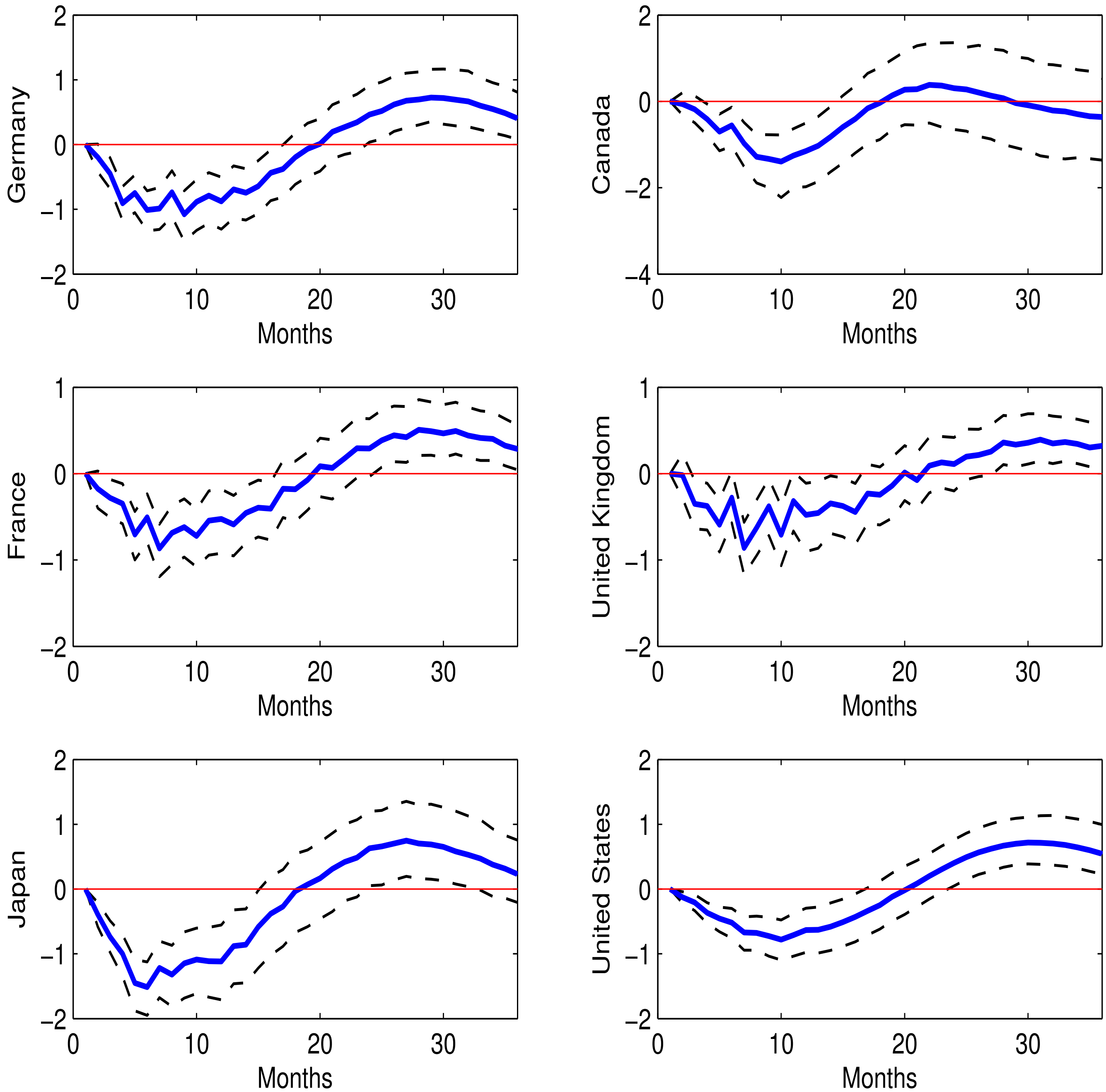
Notes: This table reports the averages and standard deviations of changes in log real exchange rates, along with the cross-country correlation of changes in log real exchange rates with cross-country differences in real equity returns, real risk-free rates, real consumption growth and real output growth. The table uses simulated series. We consider two models: (1) our benchmark model with time-varying risk of disaster, where the domestic country is more risky (restated for convenience); (2) a long sample which includes disaster realizations

Table 16: Carry Trade Excess Returns — Robustness

	$E(r^e_{t+1})$	$\sigma(r^e_{t+1})$	$(r^e_{t+1}, \Delta c)$	$(r^e_{t+1}, \Delta c^\star)$	(r^e_{t+1}, r^m_{t+1})	$(r^e_{t+1}, r^{m\star}_{t+1})$	β_{UIP}
Benchmark	1.10	6.41	-0.12	-0.58	0.91	0.71	-2.86
RBC	0.05	3.17	0.63	-0.63	0.63	-0.63	0.99
Small sample Benchmark	1.11	6.33	-0.06	-0.59	0.89	0.64	-5.08
Small sample RBC	0.04	3.16	0.63	-0.63	0.63	-0.63	-4.02
Sample with Disasters	0.98	6.49	0.18	0.07	0.90	0.69	-2.07
Defaultable debt	1.00	6.33	-0.12	-0.59	0.91	0.71	-2.85
Constant probability	0.47	3.17	0.63	-0.63	0.63	-0.63	0.93
Low risk aversion	0.04	0.55	0.58	-0.61	0.44	-0.44	0.22
Low IES	1.02	6.12	0.75	0.08	0.91	0.69	-2.80
Lower TFP vol. in home	1.07	6.99	-0.30	-0.69	0.80	0.41	-2.82
High correlation of TFP	1.08	6.19	-0.19	-0.53	0.92	0.76	-2.87

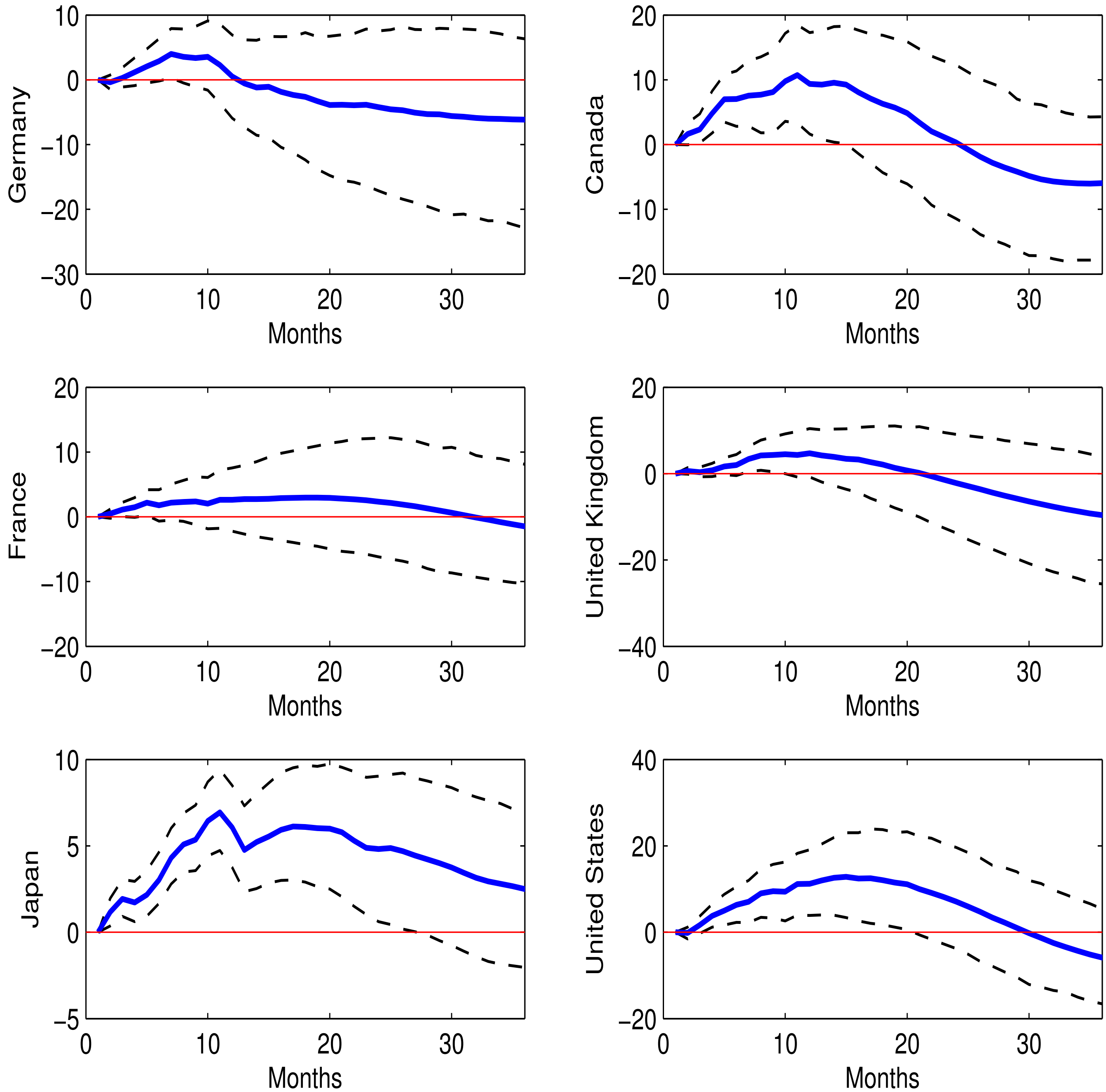
Notes: This table reports the averages and standard deviations of carry trade excess returns, along with the cross-country correlation of these excess returns with real consumption growth and real stock market returns. The last column reports the UIP slope coefficient. We consider two models: (1) our benchmark model with time-varying risk of disaster, where the domestic country is more risky (restated for convenience); (2) a long sample which includes disaster realizations.

Figure 8: Response of Industrial Production to a Shock on Average Realized Volatility



This figure plots the impulse response functions of industrial production to a one-standard deviation shock on average volatility in the following G7 countries: Canada, France, Germany, Japan, United Kingdom, and United States. Data are monthly. The sample is 1970.1 – 2009.12, except for the United Kingdom (1971.1 – 2009.12) and Canada (1995.1 – 2009.12). Volatility measures correspond to the standard deviations of equity returns over calendar months. The average volatility is the mean of these different standard deviations over the G7 countries. VARs contain the following variables: market returns, volatility, and industrial production.

Figure 9: Response of Unemployment to a Shock on Average Realized Volatility



This figure plots the impulse response functions of unemployment rates to a one-standard deviation shock on average volatility in the following G7 countries: Canada, France, Germany, Japan, United Kingdom, and United States. Data are monthly. The sample is 1970.1 – 2009.12, except for France (1978.1 – 2009.12) and Germany (1992.1 – 2009.12). Volatility measures correspond to the standard deviations of equity returns over calendar months. The average volatility is the mean of these different standard deviations over the G7 countries. VARs contain the following variables: market returns, volatility, and unemployment rates.