Consistent Expectations and the Behavior of Exchange Rates

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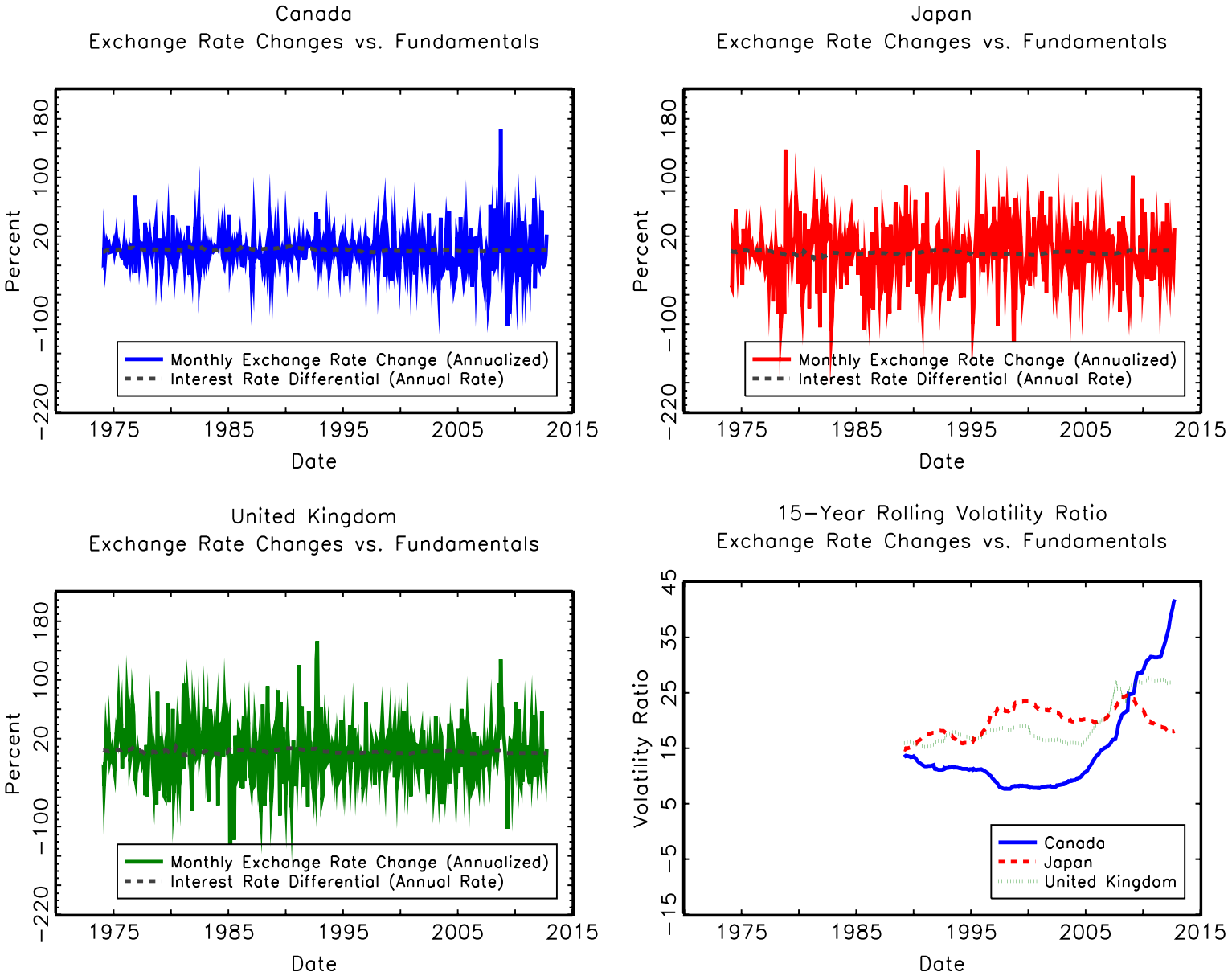
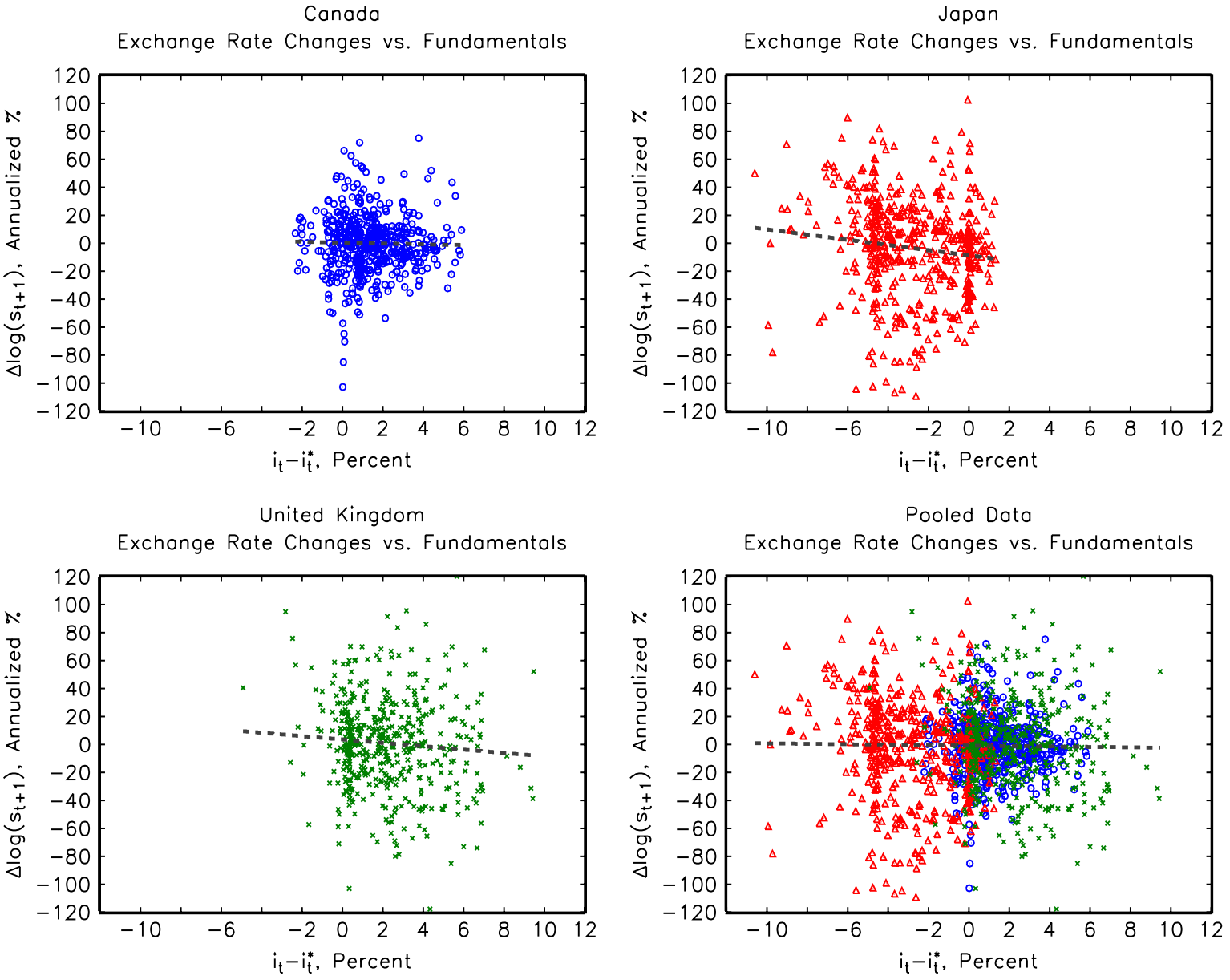
Motivations I: Exchange Rate Disconnect Puzzle

- Meese and Rogoff(1983) show that economic fundamentals do not help forecast the exchange rate better than the random walk model.
- The weak linkage between the exchange rate and its economic fundamentals remains remarkably robust (Cheung, Chinn and Pascual(2005), Sarno(2005)).
- The empirical links between fundamentals and exchange rates are generally unstable (Bacchetta and Van Wincoop(2004,2013)).
- Exchange rates may help predict fundamentals but not vice versa (Engel and West(2005)).
- Ko and Ogaki(2013) find much weaker evidence of predictability based on an improved test.

Motivations II: Excess Volatility Puzzle

- The exchange rate also appears too volatile relative to its economic fundamentals (Huang(1981), Wadhwani(1987), Bartolini and Giorgianni(2001)).
- Engel and West(2006) show that a standard rational expectations model substantially under-predicts the observed volatility.
- West(1987) points out that the exchange rate volatility can only be reconciled with the fundamentals if one allows for large amounts of shifts in the so-called unobserved fundamentals.
- Balke, Ma and Wohar(2013) decompose the U.K./U.S. exchange rate of more than a century and find most exchange rate variations come from the unobserved money demand shifters.


Canada
Exchange Rate Changes vs. Fundamentals
Percent
Date
Monthly Exchange Rate Change (Annualized)
Interest Rate Differential (Annual Rate)
Japan
Exchange Rate Changes vs. Fundamentals
Percent
Date
Monthly Exchange Rate Change (Annualized)
Interest Rate Differential (Annual Rate)
United Kingdom
Exchange Rate Changes vs. Fundamentals
Percent
Date
Monthly Exchange Rate Change (Annualized)
Interest Rate Differential (Annual Rate)
15−Year Rolling Volatility Ratio
Exchange Rate Changes vs. Fundamentals
Volatility Ratio
Date
Canada
Japan
United Kingdom


Canada
Exchange Rate Changes vs. Fundamentals
Japan
Exchange Rate Changes vs. Fundamentals
United Kingdom
Exchange Rate Changes vs. Fundamentals
Pooled Data
Exchange Rate Changes vs. Fundamentals
Δlog(s_{t+1}), Annualized %
i_t−i*_t, Percent
120
100
80
60
40
20
0
−20
−40
−60
−80
−100
−120
−10
−6
−2
0
2
4
6
8
10
12

Motivations III: Forward Premium Anomaly

- In theory, a currency traded at a premium in the forward market predicts a subsequent appreciation in the spot market.
- Uncovered Interest Parity implies that the interest rate differential predicts the future exchange rate change.
- Fama(1984) regresses the exchange rate change on the lagged interest rate differential and finds that the prediction has the opposite sign.
- Efforts to resolve the UIP puzzle include:
  - relating carry trade profits to compensations for bearing fundamental risks within the rational expectation framework
  - departures from models of fully-rational expectations

Rational Expectations Approach

- Lustig and Verdelhan(2007): carry trade profits stem from their comovements with the agent's consumption-based marginal utility.
- Burside(2011): their model is weakly identified, which renders their empirical evidence likely spurious.
- Burnside, Eichenbaum and Rebelo(2011): no statistically significant correlations between carry-trade profits and conventional risk factors.
- Verdelhan(2010): a solution based on the habits model of Campbell and Cochrane(1999).
- However, the implication that investors expect low returns in good time is at odds with a wide variety of survey evidence (see e.g. Greenwood and Shleifer(2013) and Jurgilas and Lansing(2013)).

Bounded Rationality and Distorted Belief

- Gourinchas and Tornell(2004): a distorted belief model of the interest rate differential - UIP puzzle
  - the crucial moving average parameter is exogenously chosen, different values for different anomalies
- Bacchetta and Van Wincoop(2009): random walk expectations and infrequent portfolio adjustments - UIP puzzle
  - relies on exogenous shocks to account for observed volatility
- Chakraborty and Evans(2008): learning model of monetary fundamentals - UIP puzzle
  - does not account for excess volatility
- Lansing(2010) proposes a near-rational model that generates excess volatility of equity prices.
- We build a near-rational model to the exchange rate based on the Taylor-rule type exchange rate model.

Preview of Findings

- Our proposed subjective forecast rule matches with features of survey data.
- The parameter in the subjective forecast rule is pinned down by the agent by matching moments of the data, in the spirit of "consistent expectations equilibrium" as defined in Hommes and Sorger(1998).
- The model results in a nearly nonstationary exchange rate at the CEE.
- The CEE is stable and learnable.
- The model generates excess volatility.
- The model generates negative Fama regression coefficient and a large time variation of it.

Taylor Rule Type Exchange Rate Model

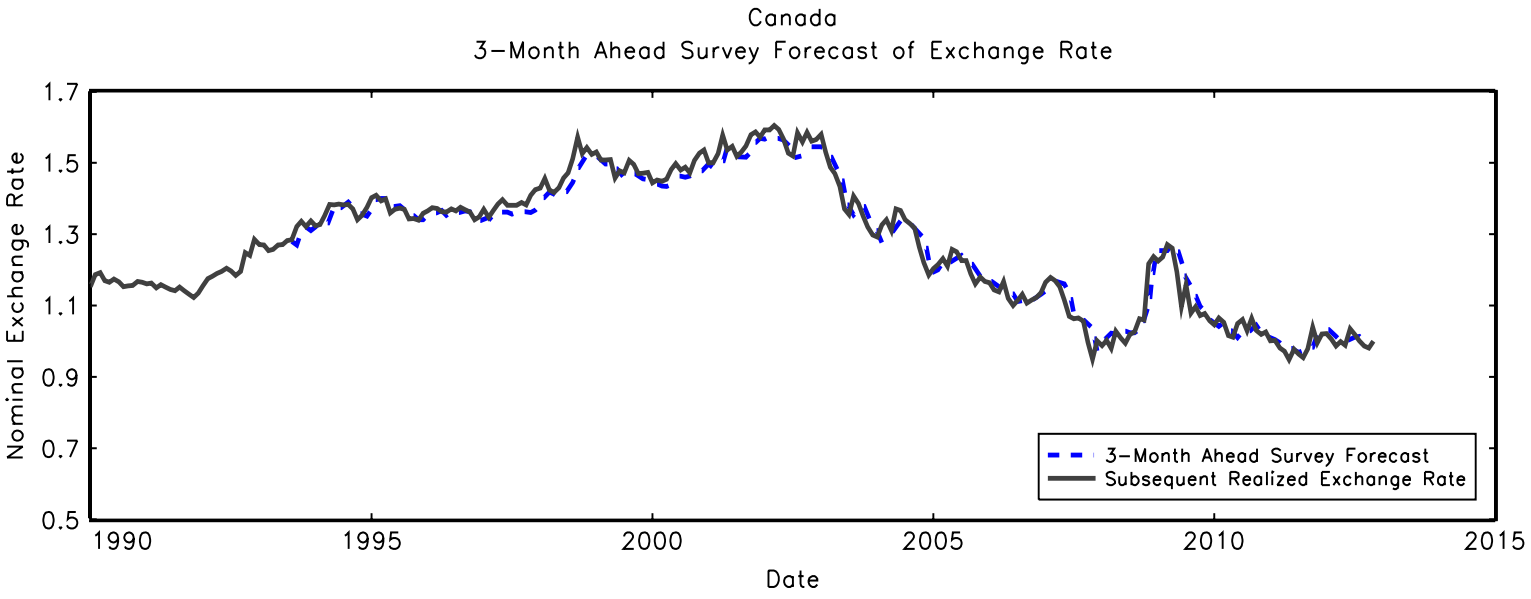
- The interest rates in home countries (Canada, Japan, UK) follow a Taylor rule with interest rate smoothing (see Clarida,Gali,and Gertler(1998), and Engel and West(2005)):
  - $i_t = \theta i_{t-1} + (1-\theta)[g_\pi \pi_t + g_y y_t + g_s(s_t - \bar{s}_t)] + u_{mt}$
  - Here $\bar{s}_t = p_t - p_t^*$ is the exchange rate target.
- The interest rate in the foreign country (US) follows a similar Taylor rule without exchange rate targeting:
  - $i_t^* = \theta i_{t-1}^* + (1-\theta)[g_\pi \pi_t^* + g_y y_t^*] + u_{mt}^*$
- The resulting interest rate differential is given by:
  - $i_t - i_t^* = \theta(i_{t-1} - i_{t-1}^*) + (1-\theta)[g_\pi(\pi_t - \pi_t^*) + g_y(y_t - y_t^*) + g_s(s_t - \bar{s}_t)] + u_{mt} - u_{mt}^*$

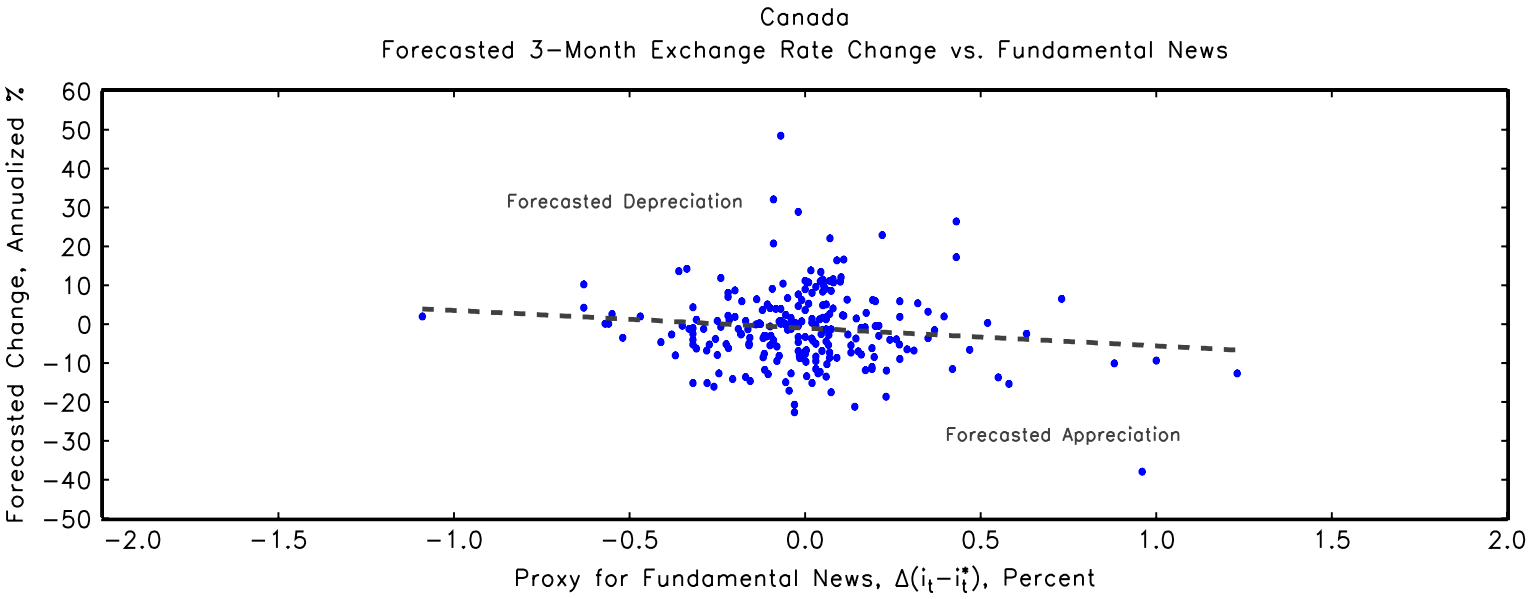
A Taylor Rule Type Exchange Rate Model

- The Uncovered Interest Parity(UIP):
  - $E_t s_{t+1} - s_t = i_t - i_t^*$
- Plug UIP into the Taylor rule and solve for the exchange rate:
- FOC: $s_t = \psi E_t s_{t+1} + x_t$
- $\psi = \frac{1}{1+(1-\theta)g_s} < 1$
- $x_t = -\psi\{\theta(i_{t-1} - i_{t-1}^*) + (1-\theta)[g_\pi(\pi_t - \pi_t^*) + g_y(y_t - y_t^*) - g_s(p_t - p_t^*)] + (u_{mt} - u_{mt}^*)\}$
- Notice that $i_t - i_t^* = -\frac{1}{\psi}x_t + (\frac{1}{\psi} - 1)s_t$

Perceived Law of Motion

- FOC: $s_t = \psi \hat{E}_t s_{t+1} + x_t$
- Fundamental variable $x_t = \rho x_{t-1} + u_t, u_t \sim N(0, \sigma_u^2)$
- The agent postulates a simple law of motion for the exchange rate:
  - $s_{t+1} = s_t + \alpha u_{t+1}$
- This proposed subjective forecast rule matches with features of survey data:
  - Dick and Menkhoff(2013) show most professional forecasters use both technical analysis and fundamentals to predict exchange rates.
  - Our survey data for Canadian exchange rates shows appreciation in response to an increase in interest rate differentials.


Canada
3−Month Ahead Survey Forecast of Exchange Rate
Nominal Exchange Rate
1.7
1.5
1.3
1.1
0.9
0.7
0.5
1990
1995
2000
2005
2010
2015
Date
3−Month Ahead Survey Forecast
Subsequent Realized Exchange Rate


Canada
Forecasted 3−Month Exchange Rate Change vs. Fundamental News
Forecasted Change, Annualized %
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
Forecasted Depreciation
Forecasted Appreciation
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
Proxy for Fundamental News, $\Delta(i_t - i_t^*)$, Percent

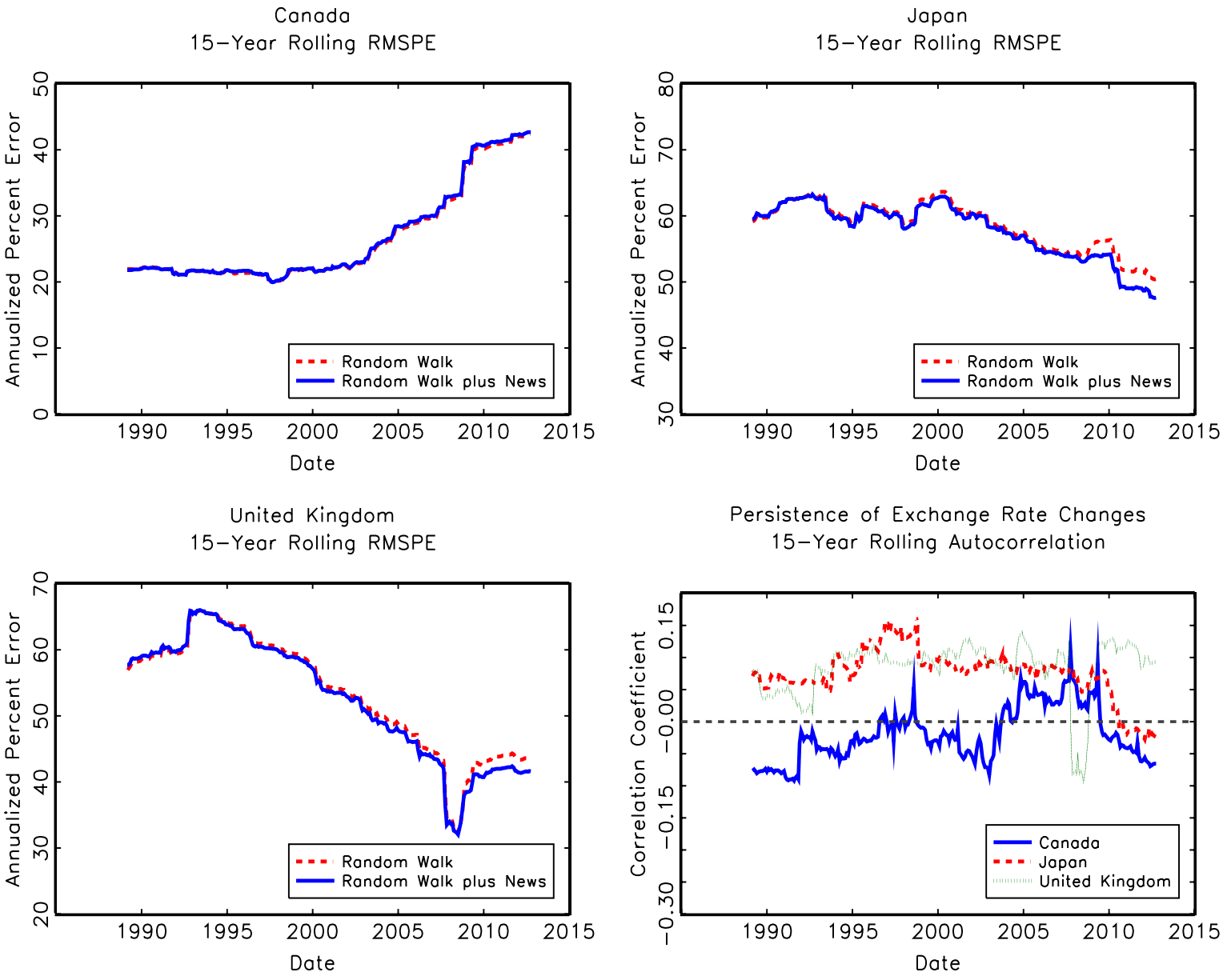
Summary Statistics,1973M01-2012M10

- RMSE with 15-yr Rolling Window

	Canada	Japan	UK
Random Walk	0.2658	0.5856	0.5328
Modified Random Walk	0.2667	0.5765	0.5258

- Exchange rates summary

	Canada	Japan	UK
$sd(\Delta s_t)$	0.2273	0.3827	0.3563
$corr(\Delta s_t, \Delta s_{t-1})$	-0.0539	0.0554	0.0933
$sd(\Delta^2 s_t)$	0.3301	0.5250	0.4803
$corr(\Delta^2 s_t, \Delta^2 s_{t-1})$	-0.5351	-0.4931	-0.4673


Canada
15−Year Rolling RMSPE
Annualized Percent Error
Date
Random Walk
Random Walk plus News
Japan
15−Year Rolling RMSPE
Annualized Percent Error
Date
Random Walk
Random Walk plus News
United Kingdom
15−Year Rolling RMSPE
Annualized Percent Error
Date
Random Walk
Random Walk plus News
Persistence of Exchange Rate Changes
15−Year Rolling Autocorrelation
Correlation Coefficient
Date
Canada
Japan
United Kingdom

CEE Exchange Rate Model

- Assume the agent can only use the lagged realization instead of the contemporaneous one to form her expectation:
  - $\hat{E}_t s_{t+1} = \hat{E}_t[s_t + \alpha u_{t+1}] = \hat{E}_t[s_{t-1} + \alpha u_t + \alpha u_{t+1}] = s_{t-1} + \alpha u_t$
- This assumption is common in adaptive learning models and avoids the simultaneity issue.
- Plug the PLM into the FOC and we obtain the ALM:
  - $s_t = \psi s_{t-1} + \psi \alpha u_t + x_t$
- Note that the agent's perception of a unit root is close to being self-fulfilling as ψ is close to 1.

Analytical Fixed Point

- Rewrite the ALM of the exchange rate:
  - $\Delta s_t = (\psi - 1)s_{t-1} + \psi\alpha u_t + x_t$
- The agent identifies α by running a regression of the exchange rate change on the fundamental news.
- $T(\alpha) = \frac{Cov(\Delta s_t, u_t)}{\sigma_u^2} = \psi\alpha + 1$
- $T(\alpha) = \alpha$ implies $\alpha^* = \frac{1}{1-\psi}$
- Since $T'(\alpha) = \psi < 1$, the fixed point is both stable and learnable.

Rational Expectation Solution

- It is straightforward to solve for the rational expectation solution:
- $s_t = \frac{x_t}{1-\rho\psi}$
- It is easy to derive:
- $Corr(s_t, s_{t-1}) = \rho$
- $Corr(\Delta s_t, \Delta s_{t-1}) = \frac{\rho-1}{2}$
- $\frac{Var(\Delta s_t)}{Var(x_t)} = \frac{2(1-\rho)}{(1-\rho\psi)^2}$

Fundamental Forecast in CEE Economy

- The forecast error of a fundamental forecast is given by:
- $err^f_{t+1} = s_{t+1} - E^f_t s_{t+1}$
  - Here $E^f_t s_{t+1} = \frac{\rho x_t}{1-\rho\psi}$
  - And $s_{t+1} = \psi s_t + \psi\alpha u_{t+1} + x_{t+1}$
- It is then straightforward to derive:
- $\frac{Var(err^f_{t+1})}{Var(x_t)} = \frac{Var(s_t)}{Var(x_t)} + \frac{\rho^2 - 2\rho\psi[\psi\alpha(1-\rho^2)+1] - 2\rho^2(1-\rho\psi)}{(1-\rho\psi)^2}$
- $\frac{Cov(err^f_{t+1}, err^f_t)}{Var(x_t)} = \psi\frac{Var(s_t)}{Var(x_t)} + \frac{\rho^2[1-(1-\rho\psi)(\psi+\rho)] - \rho(1+\psi^2)[\psi\alpha(1-\rho^2)+1]}{(1-\rho\psi)^2}$
- And $Corr(err^f_{t+1}, err^f_t) = \frac{Cov(err^f_{t+1}, err^f_t)}{Var(err^f_{t+1})} \neq 0$ in general.

Data

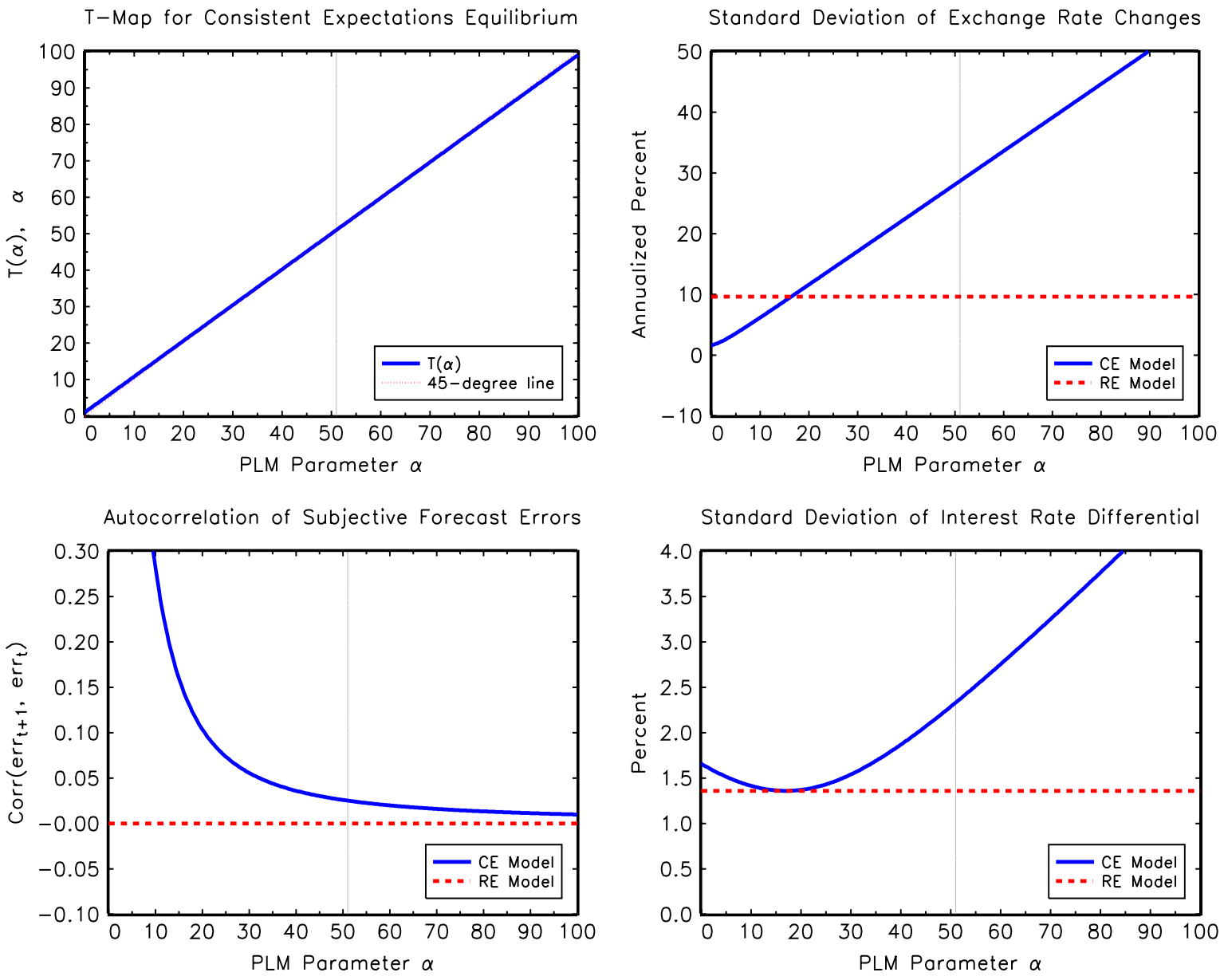
- Data source: International Financial Statistics.
- Frequency and sample period: monthly from 1973M01 to 2012M10.
- Data:
  - End-of-period exchange rate (number of home currency per US dollar)
  - Industrial production
  - Consumer price index
  - Short-term interest rate
- We use a quadratic trend to obtain a measure of the output gap (HP filter produces similar results)
- Baseline parameter values in Taylor rule (see e.g. CGG 1998): $\theta = 0.8, g_s = 0.1, g_\pi = 1.5, g_y = 0.5$

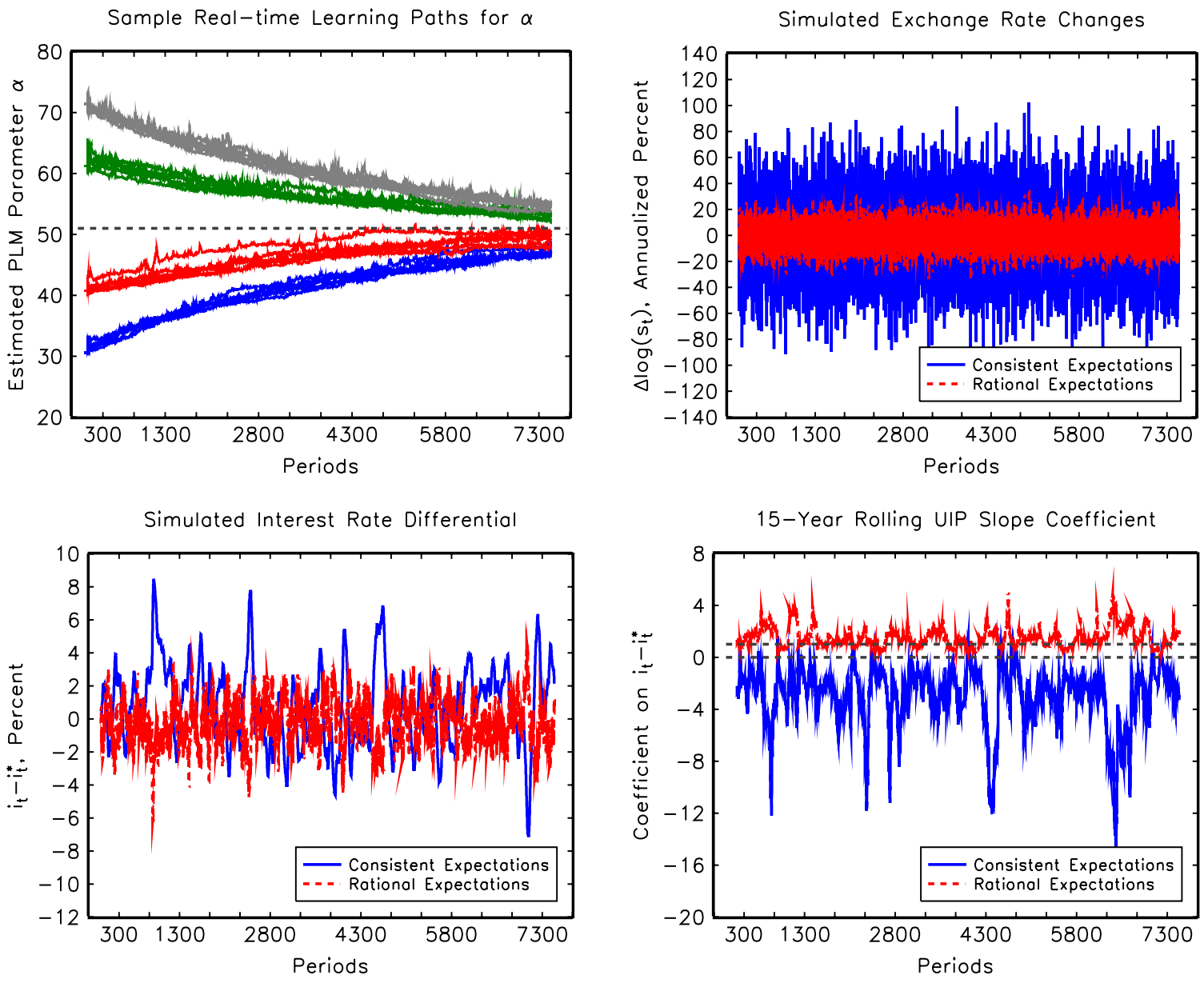
Summary Statistics of Fundamentals

	Canada	Japan	UK
$sd(i_t - i_t^*)$	0.0162	0.0235	0.0218
$corr(i_t - i_t^*, i_{t-1} - i_{t-1}^*)$	0.9556	0.9721	0.9535
$sd(x_t)$	0.0165	0.0253	0.0221
$corr(x_t, x_{t-1})$	0.9594	0.9758	0.9555
$skew(i_t - i_t^*)$	0.4166	-0.3478	0.5558
$kurt(i_t - i_t^*)$	2.9180	2.7254	3.2678

Consistent Expectations Equilibrium

- Baseline parameter values in CEE model:
  - Implied discount factor (from the Taylor rule parameters): $\psi = 0.9804$
  - Fundamental variables: $sd(x_t) = 0.02, \rho = 0.96$
- CEE solution: $\alpha^* = \frac{1}{1-\psi} = 51$
- Since $0 < T'(\alpha) = \psi < 1$, the fixed point is stable under learning.


T−Map for Consistent Expectations Equilibrium
T(α), α
PLM Parameter α
T(α)
45−degree line
Standard Deviation of Exchange Rate Changes
Annualized Percent
PLM Parameter α
CE Model
RE Model
Autocorrelation of Subjective Forecast Errors
Corr(err_{t+1}, err_t)
PLM Parameter α
CE Model
RE Model
Standard Deviation of Interest Rate Differential
Percent
PLM Parameter α
CE Model
RE Model


Sample Real−time Learning Paths for α
Estimated PLM Parameter α
Periods
Simulated Exchange Rate Changes
Δlog(s_t), Annualized Percent
Periods
Consistent Expectations
Rational Expectations
Simulated Interest Rate Differential
i_t−i*_t, Percent
Periods
Consistent Expectations
Rational Expectations
15−Year Rolling UIP Slope Coefficient
Coefficient on i_t−i*_t
Periods
Consistent Expectations
Rational Expectations

Simulations Results

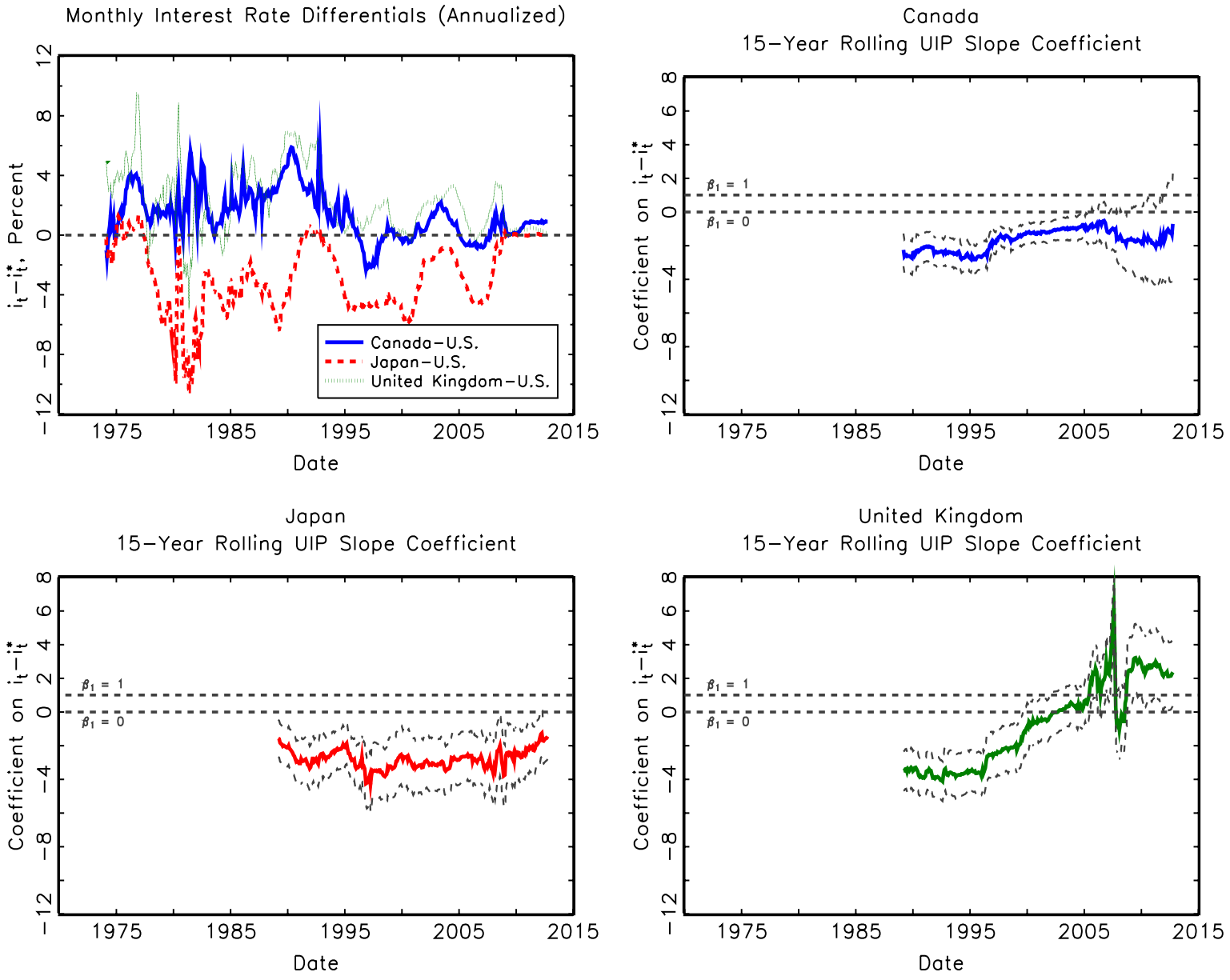
	RE	CEE	Canada	Japan	UK
$sd(\Delta s_t)$	0.0955	0.2848	0.2273	0.3827	0.3563
$corr(\Delta s_t, \Delta s_{t-1})$	-0.0287	-0.0015	-0.0539	0.0554	0.0933
$sd(\Delta^2 s_t)$	0.1370	0.4031	0.3301	0.5250	0.4803
$corr(\Delta^2 s_t, \Delta^2 s_{t-1})$	-0.5064	-0.5057	-0.5351	-0.4931	-0.4673
$sd(i_t - i_t^*)$	0.0139	0.0241	0.0162	0.0235	0.0218

- Forecast errors

	fundamental forecast in CEE economy	CE model	RE model
$corr(err_t, err_{t-1})$	0.9300	0.0195	0.0143
$corr(err_t, err_{t-2})$	0.8865	-0.0158	0.0027
$corr(err_t, err_{t-3})$	0.8499	0.0043	0.0203

Fama Regression I

- Fama(1984) regression: $\Delta s_{t+1} = c + \beta(i_t - i_t^*) + \epsilon_{t+1}$
  - UIP implies $\beta = 1$ in theory.
  - Using the observed data β estimates are often negative.
- The UIP puzzle is also about the time-variation of β estimates:
  - A growing literature have documented and tried to model this feature, see e.g., Baillie and Kilic(2006), Baillie and Chang(2011), Bansal(1997), and Ding and Ma(2012).
- We find that our CEE model generates negative β estimates and a large time-variation of it, which are broadly similar to those obtained using the actual data.


Monthly Interest Rate Differentials (Annualized)
$i_t - i_t^*$, Percent
Canada−U.S.
Japan−U.S.
United Kingdom−U.S.
Date
Canada
15−Year Rolling UIP Slope Coefficient
Coefficient on $i_t - i_t^*$
$\beta_1 = 1$
$\beta_1 = 0$
Date
Japan
15−Year Rolling UIP Slope Coefficient
Coefficient on $i_t - i_t^*$
$\beta_1 = 1$
$\beta_1 = 0$
Date
United Kingdom
15−Year Rolling UIP Slope Coefficient
Coefficient on $i_t - i_t^*$
$\beta_1 = 1$
$\beta_1 = 0$
Date

Fama Regression II

- We can show that in CEE the β estimate in Fama regression is negative.
- Plug the ALM into the interest rate differential formula to get: $E_{t-1}(i_t - i_t^*) = (1-\psi)s_{t-1} - \rho x_{t-1} = -E_{t-1}\Delta s_t$
- By definition: $\hat{\beta} = \frac{Cov(\Delta s_t,(i_{t-1}-i_{t-1}^*))}{Var(i_{t-1}-i_{t-1}^*)} = \frac{-Cov((i_t-i_t^*),(i_{t-1}-i_{t-1}^*))}{Var(i_{t-1}-i_{t-1}^*)}$
- And we have:
- $\frac{Var(i_t-i_t^*)}{Var(s_t)} = \frac{(1-\psi)^2}{\psi^2} + \{\frac{1}{\psi^2} - \frac{2(1-\psi)[\psi\alpha(1-\rho^2)+1]}{\psi^2(1-\rho\psi)}\frac{Var(x_t)}{Var(s_t)}\}$
- $\frac{Cov((i_t-i_t^*),(i_{t-1}-i_{t-1}^*))}{Var(s_t)} =$
$\frac{(1-\psi)^2}{\psi^2}Corr(s_t, s_{t-1}) + \{\frac{\rho}{\psi} - \frac{(1-\psi)(\rho+\psi)[\psi\alpha(1-\rho^2)+1]}{\psi^2(1-\rho\psi)}\}\frac{Var(x_t)}{Var(s_t)}$

Conclusions

- We allow the agent to incorporate fundamental news into an otherwise simple time-series model to form the exchange rate expectations in a Taylor rule type exchange rate model.
- At the consistent expectations equilibrium, the parameter in the subjective forecast rule is pinned down by the agent using the observed data in the CEE economy.
- The CEE model generates volatility that is broadly similar to that observed in the actual exchange rates data for several countries.
- The CEE model also produces negative β estimate and a large time variation of it in the Fama regression, which are broadly consistent with these obtained using the actual data.