

On the Unstable Relationship between Exchange Rates and Macroeconomic Fundamentals

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Some Background

- Anecdotal, survey and econometric evidence all suggest that the relationship between exchange rates and macro fundamentals is highly unstable
- Parameter instability has been mentioned as a major cause of poor forecasting performance
- Proposed as an explanation of the Meese-Rogoff puzzle: macro fundamentals cannot improve the out-of-sample fit

Anecdotal Evidence

- Widely reported in the financial press that traders regularly change the weight they attach to different macro indicators
- Two typical examples:

The dollar's latest stumble ... came despite optimistic economic data from the US. But analysts said the movement of the US currency was no longer driven by growth fundamentals. All the focus is on the deficit now. . . FT, Dec. 1, 2003

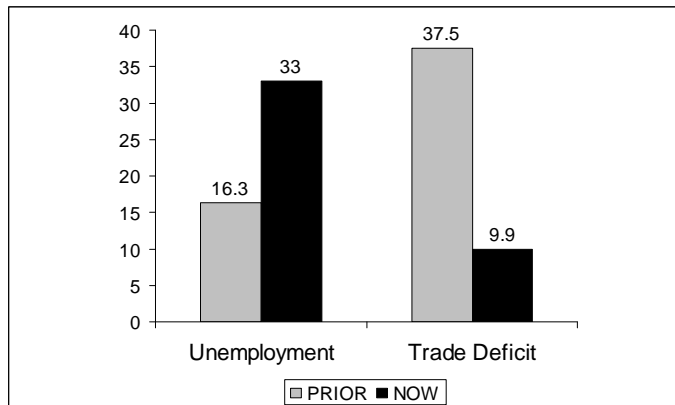
The dollar's resilience in the wake of dire US economic data has raised the prospect that the currency market may be experiencing one of its periodic changes in focus. FT, Feb. 11, 2008.

The Scapegoat Effect

- Change in focus: 'excessive' weight given to some variable over some period
- In previous paper, we called this a *scapegoat* effect (Bacchetta-van Wincoop, AER 2004)

Survey Evidence

Survey U.S. FX traders in 1998 (Cheung-Chinn, JIMF 2001):
Which economic announcements have the biggest impact on
the foreign exchange market, five years ago vs. now?



The Scapegoat Effect: Econometric Evidence

- Sarno and Valente (JEEA 2008) find that the set of variables that has the best fit in an exchange rate equation changes continuously over time
- Other papers (Wolf (1987), Schinasi and Swamy (1989) and Rossi (2006)) estimate a given process for the parameters and find that coefficients are very unstable
- Instability also found with high-frequency data. Faust et al. (JME, 2007) look at the impact of macroeconomic announcements on 5 min. exchange rate changes

Goals of the Paper

- 1 Show that significant instability in the relationship between exchange rates and fundamentals naturally results from a model with
 - 1 incomplete information about structural parameters
 - 2 high uncertainty about the level of structural parameters
 - 3 although very gradual changes in parameters
- 2 Investigate implications of this instability for statistical properties of exchange rates and interest rates
 - Examine in particular the Meese-Rogoff puzzle

Role of Incomplete Information

- Assume that structural parameters change very gradually, but can change a lot over a long period of time (several decades or century)
 - E.g. changes in institutions or technology, financial innovation
- Since these parameters are not observed, this creates significant uncertainty about their levels
- This in turn gives rise to scapegoat effects
- If unobserved fundamentals change exchange rate, nonetheless blamed on observed fundamentals
- e.g. large dollar depreciation blame on U.S. current account deficit as this is a natural scapegoat: expectations of parameters change and temporarily the current account indeed gets more weight

Model or Parameter Uncertainty

- A large literature is developing both in macroeconomics and in finance
- E.g. in finance, Pastor and Veronesi (2009): "Parameter uncertainty is ubiquitous in finance"
- In macroeconomics, see Hansen and Sargent (2008)
- In our model, agents know the model, but not the value of some parameters
- Use the model to form expectations, as is typical with rational expectations
- Focus on exchange rates, but basic idea could apply to other forward-looking variables

Basic Idea

- Start from standard exchange rate model (Engel-West, JPE 2005)

$$s_t = (1 - \lambda) \left[F_t + b_t + \sum_{j=1}^{\infty} \lambda^j E_t (F_{t+j} + b_{t+j}) \right] - \lambda \left[\phi_t + \sum_{j=1}^{\infty} \lambda^j E_t \phi_{t+j} \right] \quad (1)$$

- s_t : log nominal exchange rate (domestic per foreign currency)
- ϕ_t : risk premium
- F_t : linear combination of observed macro fundamentals f_{it} :

$$F_t = \mathbf{f}'_t \boldsymbol{\beta}$$

- $\mathbf{f}_t = (f_{1t}, f_{2t}, \dots, f_{Nt})'$
- $\boldsymbol{\beta} = (\beta_1, \beta_2, \dots, \beta_N)'$
- b_t : unobserved macro fundamentals

Basic Idea

- Basic assumption: β is not observable
- Agents know the fundamentals \mathbf{f}_t and can observe $F_t + b_t$
- Moreover, β changes over time: agents keep learning
- We assume:

$$\Delta F_t = \Delta \mathbf{f}_t' \beta_t$$

- Agents estimate β_t
- This estimate can be very volatile, which creates the unstable relationship between exchange rates and fundamentals

Specific Model

- Standard two-country monetary model
- First consider constant and known coefficients

$$E_t s_{t+1} - s_t = i_t - i_t^* + \phi_t \quad (2)$$

$$s_t = p_t - p_t^* \quad (3)$$

$$\mu m_t = p_t - \alpha i_t + \gamma' \mathbf{z}_t + v_t \quad (4)$$

$$\mu m_t^* = p_t^* - \alpha i_t^* + \gamma' \mathbf{z}_t^* + v_t^* \quad (5)$$

- \mathbf{z}_t and \mathbf{z}_t^* : vectors of variables affecting money demand
- v_t and v_t^* : linear velocity shocks

- Combining the last 3 equations:

$$i_t - i_t^* = \frac{1}{\alpha} s_t - \frac{1}{\alpha} \underbrace{[\mu(m_t - m_t^*) - \gamma'(z_t - z_t^*)]}_{F_t} - \frac{1}{\alpha} \underbrace{(v_t - v_t^*)}_{b_t} \quad (6)$$

- Or:

$$i_t - i_t^* = \frac{1}{\alpha} s_t - \frac{1}{\alpha} (F_t + b_t) \quad (7)$$

- Combining equations (2) and (7), integrating forward and assuming no bubble gives equation (1), where

$$\lambda = \frac{\alpha}{1 + \alpha}$$

- Again:

$$s_t = (1 - \lambda) \left[F_t + b_t + \sum_{j=1}^{\infty} \lambda^j E_t (F_{t+j} + b_{t+j}) \right] - \lambda \left[\phi_t + \sum_{j=1}^{\infty} \lambda^j E_t \phi_{t+j} \right] \quad (8)$$

- Special case:

- 1 $\phi_t = 0, \forall t$
- 2 $b_t = \varepsilon_t^b$ with $\varepsilon_t^b \sim N(0, \sigma_b^2)$
- 3 $\Delta f_{nt} = \varepsilon_{nt}^f$ with $\varepsilon_{nt}^f \sim N(0, \sigma_f^2)$

- In this case, (1) implies:

$$\Delta s_t = \Delta \mathbf{f}'_t \boldsymbol{\beta} + (1 - \lambda) \Delta b_t \quad (9)$$

- The impact of a change in fundamental f_{nt} on the exchange rate is simply given by β_n :

$$\frac{\partial \Delta s_t}{\partial \Delta f_{nt}} = \beta_n$$

Unknown and time-varying parameters

- We consider the money market (4) in first difference:

$$\mu_t \Delta m_t = \Delta p_t - \alpha \Delta i_t + \gamma_t' \Delta \mathbf{z}_t + \Delta v_t \quad (10)$$

- Both sides are stationary
- These assumptions still yield equation (1), but we now have:

$$\Delta F_t = \Delta \mathbf{f}_t' \boldsymbol{\beta}_t \quad (11)$$

where

$$\mathbf{f}_t = \begin{pmatrix} m_t \\ \mathbf{z}_t \end{pmatrix} ; \quad \boldsymbol{\beta}_t = \begin{pmatrix} \mu_t \\ \gamma_t \end{pmatrix} \quad (12)$$

- We will also write $\boldsymbol{\beta}_t = (\beta_{1t}, \beta_{2t}, \dots, \beta_{Nt})'$

- Special case:

$$\Delta s_t = (1 - \lambda)\Delta F_t + (1 - \lambda)\Delta b_t + \lambda(E_t F_t - E_{t-1} F_{t-1}) \quad (13)$$

- Since λ is close to 1, most of the weight is on expected values
- Assume that parameters are known after T periods (T very large). We can write (13) as:

$$\begin{aligned} \Delta s_t = & \Delta \mathbf{f}'_t ((1 - \lambda)\boldsymbol{\beta}_t + \lambda E_t \boldsymbol{\beta}_t) + (1 - \lambda)\Delta b_t \\ & + \lambda \sum_{i=1}^T \Delta \mathbf{f}'_{t-i} (E_t \boldsymbol{\beta}_{t-i} - E_{t-1} \boldsymbol{\beta}_{t-i}) \end{aligned} \quad (14)$$

- Impact of fundamentals on the exchange rate

$$\frac{\partial \Delta s_t}{\partial \Delta f_{nt}} = (1 - \lambda)\beta_{nt} + \lambda E_t \beta_{nt} + \lambda \sum_{i=0}^T \Delta \mathbf{f}'_{t-i} \frac{\partial E_t \boldsymbol{\beta}_{t-i}}{\partial \Delta f_{nt}} \quad (15)$$

Expectations of Parameters

- Assume that parameters follow the process

$$\beta_{nt} = \beta_n + \sum_{i=1}^T \theta_{ni} \varepsilon_{n,t-i+1} \quad (16)$$

where $\varepsilon_{nt} \sim N(0, \sigma_\beta^2)$

- Or:

$$\beta_t = \beta + \Theta \xi_t \quad (17)$$

- ξ_t : NT vector that stacks all the vectors $\xi_{nt} = (\varepsilon_{nt}, \dots, \varepsilon_{n,t-T+1})'$
- Θ : $N \times NT$ matrix

- Compute expectations of parameter innovations over the past T periods through signal extraction
- Two sources of information:
 - 1 $\varepsilon_{nt} \sim N(0, \sigma_\beta^2)$
 - 2 $F_t + b_t = \sum_{i=0}^{\infty} \Delta \mathbf{f}'_{t-1} \boldsymbol{\beta}_{t-1} + b_t$

Solution Signal Extraction

- Using Kalman filter:

$$E_t \beta_{t-i} = \hat{\beta}_{t-i} + \Omega_{ti} \omega_t \quad (18)$$

- $\omega'_t = (\zeta'_t, \varepsilon_t^b, \varepsilon_{t-1}^b, \dots, \varepsilon_{t-T+1}^b)$
- $\hat{\beta}_{t-i}$: β plus (for $i > 1$) a vector that depends on parameter innovations more than T periods ago that are known time t
- Ω_{ti} : complex matrix that depends in particular on $\Delta \mathbf{f}_{t-i}$ for $0 < i < T + 1$

Some Intuition

- Remember:

$$\frac{\partial \Delta s_t}{\partial \Delta f_{nt}} = (1 - \lambda)\beta_{nt} + \lambda E_t \beta_{nt} + \lambda \sum_{i=0}^T \Delta \mathbf{f}'_{t-i} \frac{\partial E_t \beta_{t-i}}{\partial \Delta f_{nt}} \quad (19)$$

- Complex expression. Look at first and second order components

- Zero order: $\frac{\partial \Delta s_t}{\partial \Delta f_{nt}}(0) = \beta_{nt}$

- First order

$$\frac{\partial \Delta s_t}{\partial \Delta f_{nt}}(1) = (1 - \lambda)(\beta_{nt} - \beta) \quad (20)$$

- Weight on structural parameter is dampened by a factor $1 - \lambda$
- Because parameter innovations do not affect the expectation of β_{nt} to the first order

- Second order

$$\frac{\partial \Delta s_t}{\partial \Delta f_{nt}}(2) = \frac{\sigma_\beta^2}{\sigma_b^2} \lambda \sum_{i=0}^{T-1} \zeta_{t,i} \varepsilon_{t-i}^b + \frac{\sigma_\beta^2}{\sigma_b^2} \lambda \vartheta_t \varepsilon_t^b \quad (21)$$

where:

$$\zeta_{t,i} = \sum_{k=i}^{T-1} \sum_{j=1}^{T-k} \theta_j \theta_{j+k} \delta_{ik} \Delta f_{n,t-k}$$

$$\vartheta_t = \sum_{i=0}^T \left(\sum_{j=1}^{T-i} \theta_j \theta_{j+i} \right) \Delta f_{n,t-i}$$

- Interaction between $\Delta f_{n,t-i}$ and ε_t^b captures the scapegoat effect
- If a large ε_t^b shock is correlated with large $\Delta f_{n,t-i}$, give large weight to f_{nt}
- Implies high volatility
- From third order component, shocks to fundamental j may affect weight of fundamental i

Numerical Exercise

- Consider a more general form of the model where:

$$\begin{aligned}\Delta f_{nt} &= \rho_f \Delta f_{n,t-1} + \varepsilon_t^f \\ b_t &= \rho_b b_{t-1} + \varepsilon_t^b \\ v_{t+1} - v_t &= \psi_1 (v_t - v_{t-1}) - \psi_2 v_t + \varepsilon_t^v\end{aligned}$$

$\varepsilon_t^v \sim N(0, \sigma_v^2)$ and v_t is the present discounted value of the risk premium:

$$v_t = \sum_{k=0}^{\infty} \lambda^k E_t \phi_{t+k}$$

- Choose the parameters θ_i for the process of β_{nt} in order to maximize the unconditional standard deviation of β_{nt} relative to the standard deviation of $\Delta \beta_{nt}$
- Calibrate to monthly data for 5 countries from 1975(9) to 2008(9)

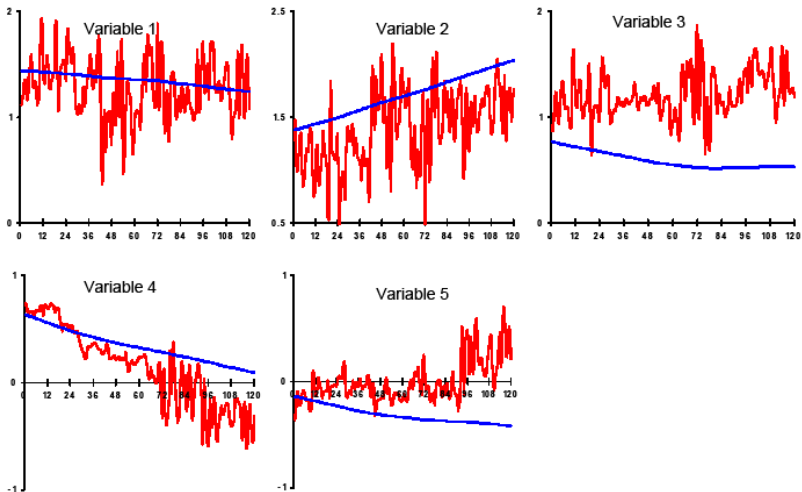
Table 1 Benchmark Parameter Assumptions[†]

T	1000
N	5
β	1
σ_β	0.0165
σ_b	2.2
ρ_b	0.96
σ_v	2.7
ϕ_1	0.06
ϕ_2	0.1
σ_f	0.125
ρ_f	0
α	33.3

Table 2 Moments: Data and Model[†]

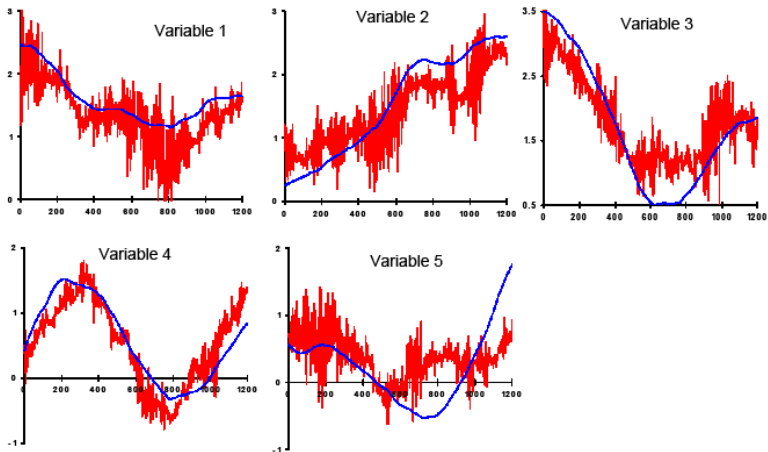
	Data	$\sigma_{\beta}=0$	Benchmark $\sigma_{\beta}=0.0165$	$\sigma_{\beta}=0.033$
Standard Deviation Δs_t	2.91	2.90	2.99	3.04
Corr($\Delta s_t, \Delta s_{t-1}$)	0.04	0.04	0.04	0.04
Standard Deviation $i_t - i_t^*$	0.22	0.23	0.23	0.23
Corr($i_t - i_t^*, i_{t-1} - i_{t-1}^*$)	0.92	0.92	0.93	0.93
cov($\Delta s_t, i_{t-1} - i_{t-1}^*$) / var($i_{t-1} - i_{t-1}^*$)	-1.25	-1.82	-1.86	-1.83
R ² monthly	0.023	0.022	0.022	0.031
s.d. Monthly Change $\partial \Delta s_t / \partial \Delta f_{\text{nr}}$	-	0	25.9	45.0
s.d. Monthly Change $\Delta \beta_{\text{nr}}$	-	0	0.30	0.61

Figure 1 Derivative Δs_t with respect to Δf_{nt} (10 years)*



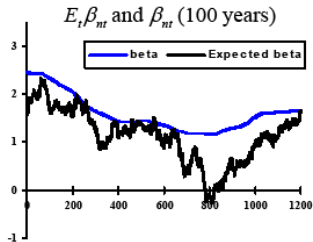
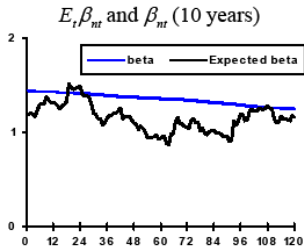
* The smooth line is β_{nt} , while the volatile line represents the derivative of Δs_t with respect to Δf_{nt} .

Figure 2 Derivative Δs_t with respect to Δf_{nt} (100 years)*

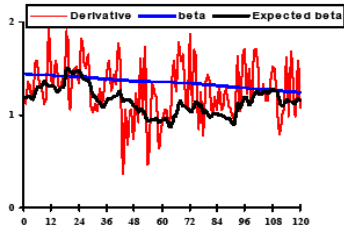


* The smooth line is β_{nt} , while the volatile line represents the derivative of Δs_t with respect to Δf_{nt} .

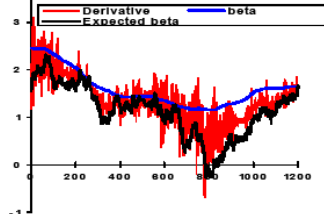
Figure 3 Expectations β_{nt} (variable 1)



$\partial\Delta s_t / \partial\Delta f_{nt}$, $E_t\beta_{nt}$, and β_{nt} (10 years)



$\partial\Delta s_t / \partial\Delta f_{nt}$, $E_t\beta_{nt}$, and β_{nt} (100 years)



Sensitivity Analysis: Process for Structural Parameters

- Crucial element: long-term uncertainty of structural parameters

$$\beta_{nt} = \beta_n + \sum_{i=1}^T \theta_{ni} \varepsilon_{n,t-i+1} \quad (22)$$

- Choose θ_{ni} so as to maximize

$$\frac{\sigma_{\beta_{nt}}}{\sigma_{\Delta\beta_{nt}}}$$

- Other set of parameters give less scapegoat
- But possible to consider other processes. E.g. infinite sum
- Gives much bigger scapegoat effect

Table 3 Scapegoat Ratio*

	$\frac{s.d.(\tilde{\beta}_{nt})}{s.d.(\Delta\beta_{nt})}$	Scapegoat ratio
Benchmark Process	319	86.3
Process 1	637	267.7
Process 2	7	1.6
Process 3	22	4.4
Process 4	49	10.1

Further Sensitivity Analysis: Scapegoat effect

- Decreases with σ_f
- Increases with ρ_f
- Increases with T
- Increases and then decreases with σ_b
- Increases and then decreases with σ_β

Impact on Out-of-Sample Forecasting

- Meese and Rogoff (1983) developed an out-of-sample test for exchange rate models
- Find that fundamentals do not help in explaining exchange rate changes
- Two Sets of Explanations:
 - ① Small sample bias
 - ② Time-varying parameters or changes in the structural model: has been suggested as an explanation by Meese and Rogoff (1983) themselves and many others

MR in the model

- We conduct the MR experiment using data generated by the model, either with constant or with time-varying coefficients
- We can match the MR results from the data
- More importantly time variation has basically no impact

Explanation

- Time variation has two effects
- On the one hand it increases the estimation error of the parameters
 - This reduces the forecasting performance
- On the other hand, with time variation there are sometimes large value of parameters: higher expected β^2 under time-varying coefficients
 - This improves the forecasting performance
- The two effects offset each other in the calibration that matches the data
- We analyze these issues in more details in a companion paper (Bacchetta, van Wincoop, and Beutler, 2009)

Conclusion

- Anecdotal, survey and econometric evidence suggest that the relationship between the exchange rate and macro variables is highly unstable
- Developed a model where such instability naturally develops from a combination of incomplete information and very gradual changes in structural parameters
- Nonetheless this unstable relationship has little impact on the statistical properties of exchange rates and the ability to forecast out of sample
- Could be applied to other forward-looking variables