Why so Glum? The Meese-Rogoff Methodology Meets the Stock Market

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Motivation

- Meese-Rogoff (1983a,b): the most devastating critique of exchange rate determination models
  - Random walk prediction of no change out-forecasts structural models estimated with historical data even given actual future fundamentals
  - Big negative effect on international finance
Not the Classic Stock Market Finding

• Well-known: difficult to out-predict a random walk for stocks

• But researchers do not give models out of sample fundamentals

(only forecasts of fundamentals)
Summary of What We Do

• Use same methodology as Meese-Rogoff, *different asset class*
  
  o Apply to broad *stock price indices* for four countries
    
    (Germany, Japan, UK, and USA)

  o Consider five different forecasting horizons (1-, 3-, 6-, 12-, and 24-months ahead)

  o Same forecasting techniques, metrics, sample period as MR

  o *Give forecasters actual future fundamentals*
Algebra of MR

• Meese Rogoff find: exchange rate models, estimated through the date on which forecast made *can’t beat a random walk* (at short horizons – up to 2 years), *despite model being given future fundamentals*
A Generic Model

\[
\begin{align*}
 s_t &= \beta(t - 1,1) f_t + x_t, \quad \text{1-period} \\
 s_{t+k} &= \beta(t-k,k) f_{t+k} + x_{t+k}, \quad \text{k-period}
\end{align*}
\]

Forecast Errors are \{x\}
Random Walk “Model”

\[ S_t = S_{t-1} + u_t \]  
(1-period)

\[ S_{t+k} = S_{t-1} + u_{t+k} \]  
(k-period)

RW: fancy way of saying forecast no change
Key, Devastating MR finding:

\[ RMSE(x) > RMSE(u) \quad k < 24 \text{ months} \]

- Models – even given information about future fundamentals – *do worse than mindless prediction of no change*, for up to 24 months in advance (sometimes greater.)
Key Questions/Results

• Q1: What happens if MR standard applied to other markets?
  - A1: Random walk “model” matches/beats other stock models, similar to Meese-Rogoff for FX!

• Q2: What does this mean in terms of familiar parametric measures of model performance, e.g. $R^2$, $\rho$?
  - A2: Not all about fundamentals information vs. residuals.

  *Autocorrelation properties of residuals important too.*
Theory for Fundamentals-Based Stock Models

• Consider standard present value model of firm value

  (Assume stocks do not give non-pecuniary returns)

\[
P_t = PV(D_{t+1}, D_{t+2}, \ldots) = PV(N_{t+1}, N_{t+2}, \ldots) \tag{1}
\]

where: \( PV() \) is present value operator; \( P_t \) is price at time \( t \); \( D \) is dividend; and \( N \) is earnings
Consider a non-stochastic (! … as in MR) discount rate $0 < \rho < 1$:

$$\text{PV}(X_{t+1}, X_{t+2}, \ldots) = E_t \sum_i (X_{t+i} \rho^i)$$

(2)

where $E()$ is expectation operator. Then for any $\theta$,

$$P_t = \theta \ E_t \sum_i (D_{t+i} \rho^i) + (1-\theta) \ E_t \sum_i (N_{t+i} \rho^i)$$

(4)
Assume growth of fundamentals is proportional:

\[
X_{t+i+1} = [1+g(X)_t]X_{t+i} + \varepsilon_{t+i+1}
\]  

(5)

where: \{\varepsilon\} is white noise, and \(g_t\) is growth rate of \(X\) estimated through \(t\), assumed to be constant from \(t\) onward.

- Fama and French: plausible for dividends and earnings
Take natural logarithms, arrive at:

\[ p_t = \beta_0 + \beta_d d_t + \beta_{dg}[1+g(d)_t] \]

\[ + \beta_n n_t + \beta_{ng}[1+g(n)_t] + \beta_i \ln(1+i_t) + u_t \]  

(8)

where: i is interest rate (added in *ad hoc* fashion); \{\beta\} coefficients of interest; lower cases denote logs.

- Will compare size of \{u\} with size of \{v\} = \( p_{t+i} - p_t \)
Three “Fundamentals-Based” Models

1. “Gordon-Growth Dividends:” $\beta_n = \beta_{ng} = \beta_i = 0$

2. “Gordon-Growth Earnings:” $\beta_d = \beta_{dg} = \beta_i = 0$

3. “Composite:” unrestricted

• All embedded in (8)
Two Alternative Atheoretical Models

• Univariate: Long Autoregression, where maximal lag length a function of sample size (Hannan), \( M = \frac{T}{\ln(T)} \)

• Multivariate: VAR of logs of prices, dividends, and earnings.
  - Lag length chosen by standard criteria (FPE/HQIC/SIC)
    - Germany (2); Japan (2); UK (3); USA (4)
Summary: We Consider 5 alternative models to random walk

1. Univariate autoregression

2. VAR (prices, dividends, earnings)

3. Gordon-growth model of dividends (levels and growth)

4. Gordon-growth model of earnings

5. Composite model: dividends, earnings, interest rates
Methodological Strategy

• Stick as close to Meese-Rogoff as possible
  

  ▪ Forecasting Period starts December 1976

  o Forecast at 1, 3, 6, 12 month horizons (add 24 to MR)
Forecasting Strategy

- Estimate version of through start of forecast period, forecast, add observation, repeat

  - Use actual future values of fundamentals (as necessary)

- That is, compare accuracy of forecast

\[ p_{t+i} = b_0 + b_d d_{t+i} + b_{dg} [1 + g(d)_{t+i}] \]
\[ + b_n n_{t+i} + b_{ng} [1 + g(n)_{t+i}] + b_i \ln(1 + i_{t+i}) \]

with “forecast” \( p_t \)
Standard Measures of Forecast Accuracy

Preferred:

\[ \text{RootMeanSquareError} \equiv \left\{ \sum_{s=0}^{N_k-1} \frac{[F(t+s+k) - A(t+s+k)]^2}{N_k} \right\}^{1/2} \]

Checks:

\[ \text{MeanAbsoluteError} \equiv \sum_{s=0}^{N_k-1} \frac{[|F(t+s+k) - A(t+s+k)|]}{N_k} \]

\[ \text{MeanError} \equiv \sum_{s=0}^{N_k-1} \frac{[F(t+s+k) - A(t+s+k)]}{N_k} \]
Data Set

• Popular, broad stock price indices covering most of national market

1. CDAX (Germany)
2. Nikkei 225 (Japan)
3. FTSE All-Share (UK)
4. S&P 500 (USA)
• Month-end prices

• Use Dividend Yield and Price/Earnings ratios to “back out”

  Dividends and Earnings

    ◦ Measurement Error, at short horizons? (lagged updates?)

    ◦ Hence, tend to be cautious, focus on longer-horizons

• Natural Logarithms of all variables

  ◦ Interest Rates: \( \ln(1+(i_t/100)) \)

• All variables nominal
Growth Rates

• Use Four Different Measures:

1. “Three-Year, Forward Looking” $\ln(x_{t+36}-x_t)/3$: Default

2. “One-Year, Forward Looking” $\ln(x_{t+12}-x_t)$

3. “Three-Year, Backward Looking” $\ln(x_t-x_{t-36})/3$

4. “One-Year, Backward Looking” $\ln(x_t-x_{t-12})$
Data Sources

- Shiller for American data
- GFD for ratios
- Datastream for Stock Price Indices
- BIS for interest rates (IMF for Japan)
Figure 1: Raw Stock Price Indices
Dividends Extracted from Dividend/Price Ratios

Figure 2: Dividends Extracted from Dividend/Price Ratios
Figure 3: Earnings Extracted from Price/Earnings Ratios
Key Result: Random Walk Model Dominates Other Models

• *All* Fundamentals-Based Models out-forecast by RW model in RMSE at *all* horizons (*despite actual future fundamentals!*)
  
  o Differences in RMSE sometimes large

• RW also beats VAR uniformly

• Only long AR beats RW, 2/12 times
  
  o Substantive difference only for 12-month Japan

• Same basic message from using MAE
Table 1: Root Mean Square Forecast Errors

<table>
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<tr>
<th>Stock Market</th>
<th>Horiz (mon)</th>
<th>RW</th>
<th>Univ</th>
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Percentage terms. 3-yr fwd-looking growth rates.
## Meese-Rogoff (1983a): Root Mean Square Forecast Errors

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The comparison with Table 1 is striking!
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Percentage terms. 3-yr fwd-looking growth rates.
Sensitivity Checks

- Use Mean Error (as well as RMSE, MAE)
- Use backward-looking (as well as forward-looking) growth rates, one- (as well as three-) year horizons
- Look at 3- and 24- (as well as 1-, 6, and 12-) month horizons
- Examine more models:
  - Random Walk with drift
- Grid-Search Techniques
• Examine more estimation techniques:
  
  o GLS (AR correction)
  
  o IV (lame: 12-month lags for levels of fundamentals)
  
  o LAD (median regression)
  
  o Add seasonal dummies

• Examine different forecasting periods
  
  o Start in November 1978 (instead of November 1976)
  
  o End in November 1980 (instead of June 1981)
What’s going on?

Study completely generic fundamentals-based model

\[ p_t = \lambda f_t + \varepsilon_t \]  \hspace{1cm} (10)

where: \( p_t \) is time \( t \) price of asset (exchange rate or stock price); \( f \) is fundamentals pre-multiplied by parameters \( \lambda \); \( \varepsilon \) is an error orthogonal to (elements of) \( f \).
Note: General Setup

- (10) can arise directly from asset-demand and arbitrage conditions as in MR.

- Can represent reduced-form obtained by solving for unobservables as in Engel and West (2005).

- Only restriction: \textit{f variables are observable} (possibly with error).
Assume error term is persistent

\[ \varepsilon_t = \rho \varepsilon_{t-1} + u_t \quad (11) \]

where \(-1 \leq \rho \leq 1\) and \(u\) is iid.

So, Variance of \( \varepsilon_t \):

\[ \text{Var}(\varepsilon) = \left[ \frac{1}{1-\rho^2} \right] \text{Var}(u). \quad (12) \]
Key Meese-Rogoff Comparison:

• Between a) root mean squared error (RMSE) of the forecast derived from (10), and b) that of the change in asset price.

• Consider one-step ahead forecast.

MR finding: RMSE of $\varepsilon$ exceeds RMSE of the first-difference of the asset price $p$:

$$\text{Var}(\varepsilon) = \frac{1}{(1-\rho^2)} \text{Var}(u) > \mathbb{E}[(p_t - p_{t-1})^2]$$

(13)
Interpretation

• Model’s forecast error variance larger than mean of the asset prices’ squared first-difference (random walk error) with step size of one month.

• ( Longer step sizes in the future)
Grinding (skip without loss)

From equation (10),

\[
(p_t - p_{t-1}) = \lambda (f_t - f_{t-1}) + \varepsilon_t - \varepsilon_{t-1} = \lambda (f_t - f_{t-1}) + (\rho - 1)\varepsilon_{t-1} + u_t \quad (14)
\]

Since \( f \) is assumed orthogonal to \( \varepsilon \) and \( u \), assuming away estimation error, we have:

\[
E[(p_t - p_{t-1})^2] = E\lambda^2 (f_t - f_{t-1})^2 + (\rho - 1)^2 \text{Var}(\varepsilon) + \text{Var}(u). \quad (15)
\]

From equation (12),

\[
E[(p_t - p_{t-1})^2] = E\lambda^2 (f_t - f_{t-1})^2 + [(\rho - 1)^2/(1 - \rho^2)] \text{Var}(u) + \text{Var}(u) \quad (16)
\]
(One-Step) **Full Information Meese-Rogoff (FIMR)** result:

$$\frac{E \lambda^2 (f_t - f_{t-1})^2}{\text{Var}(u)} < \frac{[1 - (\rho^2 - 2\rho + 1) - (1 - \rho^2)]}{(1 - \rho^2)} = \frac{2\rho - 1}{(1 - \rho^2)}$$  \hspace{1cm} (17)

or

$$\frac{E \lambda^2 (f_t - f_{t-1})^2}{\text{Var}(\epsilon)} < 2\rho - 1$$  \hspace{1cm} (17a)
Intuition

The random walk is likely to have a lower RMSE than the forecasting model (FIMR holds) when either:

a) fundamentals have low explanatory power \([\text{low } \mathbb{E}\lambda^2(f_t - f_{t-1})^2]\); or

b) the forecasting residual \((\varepsilon)\) or its innovation \((u)\) has a large variance; or

c) when the residual is highly persistent \((\text{high } \rho)\).
More Intuition

• When model performs well, Meese-Rogoff result less likely (sensible)

• Two senses in which model can work well:
  o Impact of expected change in the fundamentals large
  o Model error small
More Interesting Result

- As $\rho \to 0$, impossible to get FIMR *regardless of the relative size of fundamentals information and residual variance.*

  - For $\rho < .5$, FIMR impossible (regardless of how informative are fundamentals)
Two Conceptual Experiments ($\rho \to 1$)

- Since $\rho$ often high, use (17) and (17a) to think about what is held constant.
**Experiment 1**

- In (17), let $\rho \to 1$ holding $[E \lambda^2(f_t - f_{t-1})^2]$ and $\text{Var}(u)$ constant:

$$\frac{E \lambda^2(f_t - f_{t-1})^2}{\text{Var}(u)} < \frac{[1 - (\rho^2 - 2\rho + 1) - (1 - \rho^2)]}{(1 - \rho^2)} = \frac{2\rho - 1}{(1 - \rho^2)}$$

- **Full Information Meese-Rogoff result condition must hold in the limit regardless of the information in fundamentals.**

- FIMR criterion leads us to discard the model because of high shock persistence, even though the fundamentals-based model contains lots of information.
**Experiment 2**

- In (17a), let $\rho \rightarrow 1$ holding $E[\lambda^2(f_t - f_{t-1})^2]$ and $\text{Var}(\varepsilon)$ constant.

- In limit, FIMR condition becomes:

$$
\frac{E\lambda^2(f_t - f_{t-1})^2}{\text{Var}(\varepsilon)} < 1
$$

or

$$
R^2 < 1 - \left[ E\lambda^2(f_t - f_{t-1})^2 \right] / \text{Var}(\varepsilon)
$$

(“low” goodness of fit implies FIMR)
FIMR Interpretation

- Meese-Rogoff measure needs to be interpreted carefully.

- How seriously one takes FIMR depends on $\rho$ (extraneous parameter?) and its meaning.
  - Errors may be persistent because the model omits some persistent fundamentals.

- Models with highly persistent errors likely to have problems meeting the FIMR criterion and thus MR.
Some FIMR Measures in Data

- Apply FIMR measure to simple Foreign Exchange models
  (updated data from MR period)

- Monetary Model of Exchange Rate:

\[ s_t = \lambda_0 + \lambda_1 (m_t - m^*_t) + \lambda_2 (i_t - i^*_t) + \lambda_3 (y_t - y^*_t) + \varepsilon_t, \]

\( s \) is log (PFX) exchange rate, \( m \) is money, \( i \) is short-term interest rate, and \( y \) is real output.
Fundamentals:

\[ f_t = \lambda_0 + \lambda_1 (m_t - m_t^*) + \lambda_2 (i_t - i_t^*) + \lambda_3 (y_t - y_t^*) \]

Expected first difference fundamental is:

\[ E(f_t - f_{t-1})^2 = E[\{\Delta(\lambda_1 (m_t - m_t^*) + \lambda_2 (i_t - i_t^*) + \lambda_3 (y_t - y_t^*))\}^2] \]
### OLS – Exchange Rate Model

**Time:** 1973m3-1981m6

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>UK</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E \lambda^2(f_t - f_{t-1})^2$</td>
<td>0.00011</td>
<td>0.00044</td>
<td>0.00007</td>
</tr>
<tr>
<td>$Var(\varepsilon)$</td>
<td>0.00997</td>
<td>0.01327</td>
<td>0.0070</td>
</tr>
<tr>
<td>$\rho$ – Simple OLS</td>
<td>0.97116</td>
<td>0.98519</td>
<td>0.9885</td>
</tr>
<tr>
<td>$\rho$ – Autocorrelogram</td>
<td>0.9526</td>
<td>0.983</td>
<td>0.9761</td>
</tr>
</tbody>
</table>
Can use estimates in (17a):

\[
\frac{E\lambda^2(f_t - f_{t-1})^2}{\text{Var}(\varepsilon)} < 2\rho - 1
\]

Germany: \[\frac{0.00011}{0.0097} = 0.1142 < 0.94232\]

UK: \[\frac{0.00044}{0.01328} = 0.3316 < 0.97038\]

Japan: \[\frac{0.00007}{0.00702} = 0.0092 < 0.9770\]

- Recall FX model passes MR for 1 month
- FIMR is tougher!
Stock Market

• FIMR standard useful if gives low-cost indicator of models performance according to full-blown MR method

• Parallel to FX results above, next apply FIMR measure to simple stock market model
Use Linearized Gordon Growth Model

\[ p_t = \beta_o + \beta_d d_t + \beta_{dg} \ln(1 + g_t^D) + \varepsilon_t, \]

where

- \( p \) the level of country’s stock index, \( d \) aggregate dividends,

\( (1 + g_t^D) \) is one plus dividend growth rate

- Estimate this model for Germany, UK, Japan and the US over the MR period, 1973m3-1981m6
Now simply estimate

\[ \lambda^2 E((f_t - f_{t-1})^2) = E[\{\Delta(\beta_d d_t + \beta_{dg} \ln(1 + g_t^D))\}^2]. \]

using stock-market data
### OLS – Stock-Market Gordon Dividend Model
**Time: 1973m3-1981m6**

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>UK</th>
<th>Japan</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda^2 E(f_t - f_{t-1})^2$</td>
<td>0.00169</td>
<td>0.00924</td>
<td>0.00001</td>
<td>0.00125</td>
</tr>
<tr>
<td>$Var(\varepsilon)$</td>
<td>0.00803</td>
<td>0.04226</td>
<td>0.03307</td>
<td>0.01248</td>
</tr>
<tr>
<td>$\rho$ – Simple OLS</td>
<td>0.98293</td>
<td>0.99692</td>
<td>0.99638</td>
<td>0.9997</td>
</tr>
<tr>
<td>$\rho$ – Autocorrelogram</td>
<td>0.9793</td>
<td>0.9921</td>
<td>0.996</td>
<td>0.9937</td>
</tr>
</tbody>
</table>
Now use estimates in expression (17a):

\[
\frac{E\lambda^2 (f_t - f_{t-1})^2}{\text{Var}(\varepsilon)} < 2\rho - 1
\]

Germany: \[ \frac{.00169}{.00802} = 0.2105 < .96586 \]

UK: \[ \frac{.00925}{.04226} = .2187 < .99384 \]

Japan: \[ \frac{.00001}{.03307} = .00038 < .99276 \]

US: \[ \frac{.00125}{.01248} = .10051 < .9994 \]
Conclusion

• International finance is in no worse shape at modeling important asset prices than domestic finance on the level of stock prices.

• The Meese-Rogoff methodology may not be revealing for any asset price, especially with a lot of persistence in the composite residual.