FX Determination & Forecasting FX Rates

Fundamental & Technical Models

- **Last Class**
- Theories of FX rates determination:

- Parity Conditions

◊ **PPP**: LOOP for a basket of goods: Same price at home or abroad.

– **Absolute PPP**:

$$S_t^{PPP} = P_d \,/\, P_f \qquad \Rightarrow \; R_t = S_t\, P_f / P_d = 1.$$

Tested with different baskets (CPI, Big Mac, Iphone)

⇒ R_t = 1 rejected by data.

– **Relative PPP** (takes into consideration fixed transactions costs):

$$s_{t,T}^{PPP} \approx (I_d - I_f)$$

Tested with a regression:

$$s_{t,T} = \alpha + \beta\,(I_d - I_f)_{t+T} + \varepsilon_{t+T}.$$

Null hypothesis is: H_0 (Relative PPP true): $\alpha=0$ and $\beta=1$

H_1 (Relative PPP not true): $\alpha\neq0$ and/or $\beta\neq1$

⇒ Rejected in the short-run, some long-run support.

• **Last Class**

- Parity Conditions (continuation)

◊ **IFE**: Same "effective" return from investing at home or abroad

$$s_{t,T}^{IFE} \approx i_d - i_f$$

Tested with a regression:

$$s_{t+T} = \alpha + \beta\,(i_d - i_f)_{t,T} + \varepsilon_{t+T}$$

Null hypothesis is: H_0 (Relative IFE true): $\alpha=0$ and $\beta=1$

H_1 (Relative IFE not true): $\alpha\neq0$ and/or $\beta\neq1$

⇒ Rejected in the short-run, some long-run support:

"Currencies with high interest rate differentials tend to depreciate."

Implication: Carry trades are, on average, profitable.

• **Last Class**

- Parity Conditions (continuation)

◊ **EH**: EH: On *average*, the future spot rate is equal to the forward rate.

$$E_t[S_{t+T}] = F_{t,T}. \qquad \Rightarrow E_t[S_{t+T} - F_{t,T}] = 0$$

Tested with a regression:

$$(S_{t+T} - F_{t,T})/S_t = \alpha + \beta\, Z_t + \varepsilon_t,$$

where Z_t represents variables used to forecast S_t, usually $(i_d - i_f)$.

Null hypothesis is: H_0 (EH true): $\alpha = 0$ and $\beta = 0$.

H_1 (EH not true): $\alpha \neq 0$ and/or $\beta \neq 0$.

⇒ Rejected. Puzzle!

Usual result: $\beta < 0$ (and significant) when $Z_t = (i_d - i_f)$.

But, the R^2 is very low.

Implication: Forward rate not a good tool to forecast S_{t+T}. Risk premium?

• **This Class**

- Structural models

◊ BOP: Trade flows determine S & D for FC

◊ Monetary Approach: Currencies are just another asset.

⇒ Rejected in the short-run, some support through event studies.

- RWM

◊ Markets are efficient. All information about future is embedded on S_t

⇒ The RWM forecasts *as well as* any other model.

• Forecasting FX Rates

• IFE: Summary:

According to IFE, S_t is set in such a way that international investors, a priori, are indifferent between investing abroad or at home. Then, carry trades are, on average, not profitable. That is,

$$s_{t,T}^{IFE} \approx i_d - i_f$$

We called this relation Uncovered IRP or UIRP.

• IFE: Evidence & Implications

No short-run evidence ⇒ Carry trades work (on average).

Burnside (2008): The average excess return of an equally weighted carry trade strategy, executed monthly, from **1976–2007**, was about **5% per year.** (& less risky: carry trade return volatility is lower than that of stocks).

Some long-run support:

"*Currencies with high interest rate differentials tend to depreciate.*"

Structural Models

- We will go over two models that incorporate different views of the FX market:

(1) BOP approach treats exchange rates as determined in flow markets.

$\Rightarrow$ Trade, portfolio investment, and direct investment.

(2) Monetarist approach treats exchange rates as any other asset price.

$\Rightarrow$ Currency is another asset in an investor's portfolio.

(1) BOP Approach

• Balance Of Payments (BOP)

BOP divides the flow of foreign currency to the domestic country into:

Current account (CA): Measures the movement of good and services + unilateral transfers.

Capital Account (KA): Measures financial transactions associated with trade + changes in the composition of international portfolios.

Official Account (OR): Measures changes in official reserves.

$\Rightarrow$ BOP = CA + KA + OR.

• As long as the country is not bankrupt, BOP = 0.

In general, OR is small $\Rightarrow$ CA ≈ – KA.

• The Balance of Trade as a determinant of exchange rates

• BOP Approach: S & D for a FC arise from the *flows* related to the BOP. That is, trade, portfolio investment, and direct investment.

BOP approach views exchange rates as determined in flow markets.

• The Balance of Trade theory simplifies the BOP approach: It postulates a relation between CA and $\mathbf{R_t}$ (= $S_t\, P_f/P_d$):

$$CA = X - M = f(\mathbf{R_t}, Y_d, Y_f).$$

In general, S_t moves to compensate a CA imbalance:

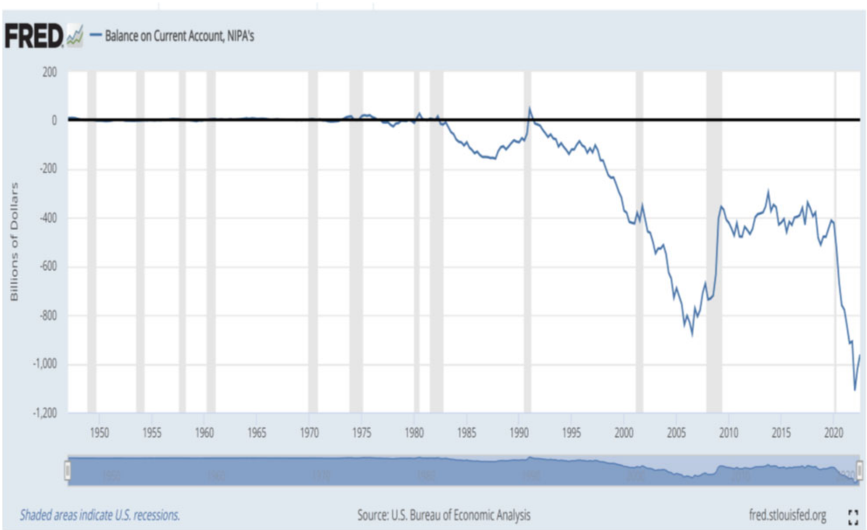
- A country with a persistent CA deficit (CA < 0). Then,

  $\mathbf{R_t}\uparrow$ ($S_t\uparrow$) $\Rightarrow$ X↑ & M↓ (CA↑)

- A country with a persistent CA surplus (CA > 0). Then,

  $\mathbf{R_t}\downarrow$ ($S_t\downarrow$) $\Rightarrow$ X↓ & M↑ (CA↓)

• US Trade Balance: 1947-2022



Note: USD **has not depreciated** according to Trade Balance Approach!

• The Macroeconomics of the BOP: Absorption Approach

In equilibrium, we can write:

$$CA = S - [I + (G - T)],$$

where

S: after-tax private savings.
I: private investment.
G: government spending.
T: national taxes.

To reduce a CA deficit, one of the following must happen in equilibrium:

i. S ↑, for a given level of I and (G – T).
ii. I ↓, for a given level of S and (G – T).
iii. G – T ↓, for a given level of S and I.

Example: Japan has a (relative) high savings rate. It is argued that this is the reason behind the persistent Japanese CA surpluses. ¶

• The Monetary Approach to the BOP

Consider the capital account (KA):

⇒ When the OR is small, KA provides the other side of the CA.

KA is assumed to depend on the interest rate differential and S_t:

$$KA = f(i_d - i_f, S_t).$$

• Look at the KA:

When KA > 0 (CA < 0) ⇒ A country **accumulates** debt or **sells** its current stock of foreign assets.

When KA < 0 (CA > 0) ⇒ A country **reduces** debt or **increases** its current stock of foreign assets.

Example: Japan may run a CA>0 without changes in the real value of JPY, as long as the Japanese continue to accumulate foreign assets. ¶

• BOP Approach: Implications

First, we ignored financial flows when we analyzed the BOP. We said:

A CA deficit (surplus) is corrected with a depreciation (appreciation) of S_t.

But once we consider the capital account, this depreciation (appreciation) might not occur. Foreigners might finance the CA imbalance.

Example: Japan may have CA>0 without any change in the real JPY because the Japanese continue to accumulate foreign assets. ¶

In the long-run the BOP approach has more precise predictions:

"*Countries will not be able to finance CA imbalances forever. Then, in the long-run persistent* CA *deficits will create KA outflows and depreciation pressures.*"

(2) Monetary Approach

Exchange rates are asset prices traded in efficient markets.

• Like other asset prices, S_t is determined by *expectations*. Current trade flows are irrelevant. (Actually, they are only relevant if the signal something about the future.)

• In a typical asset approach model we have:
- Assets denominated in DC & FC.
- A *high degree of capital mobility* between those assets.
- S_t moves to bring equilibrium to markets.

We need to be precise about the assets an investor considers.

Example: An investor considers only domestic and foreign money. Then, only news related to these assets will move S_t.

• A Simple Monetary Approach Model

Assets: Domestic money

Foreign money.

Equilibrium condition: QTM relation:

$$M_{S,j}\, V_j = P_j\, Y_j \qquad j = \text{domestic country, foreign country.}$$

S_t: Determined by Absolute PPP (= P_d/P_f):

$$S_t = (V_d/V_f) * (Y_f/Y_d) * (M_{S,d}/M_{S,f}),$$

V_j: Velocity of money of country j,

Y_j: Real output of country j,

$M_{S,j}$: Money Supply of country j (equilibrium: $M_S = L_D$ (money demand))

Recall that $x_{t,T} = (X_{t+T} - X_t)/X_t \approx \log(X_{t+T}) - \log(X_t)$ (⇒ a growth rate).

Assuming V_j is constant, we express the model in changes:

$$\Rightarrow s_{t,T} = y_{f,T} - y_{d,T} + m_{S,d,t} - m_{S,f,t}$$

• A Simple Monetary Approach Model

The simple Monetary Model produces the following model for $s_{t,T}$:

$$\Rightarrow s_{t,T} = y_{f,T} - y_{d,T} + m_{S,d,t} - m_{S,f,t}.$$

• Monetary Approach: Implications

– A stable monetary policy –i.e., low $m_{S,d,t}$– tends to appreciate the DC.

– Economic growth –i.e., $y_{d,T} > 0$– tends to appreciate the DC.

But, keep in mind that all variables are in relative terms.

Note: S_t behaves like any other speculative asset price: S_t changes whenever relevant information –about money growth & GDP growth– is released.

• Monetary Approach: Application

Example: Forecasting S_t with the simple monetarist model.
Model:

$$s_{t,T} = y_{f,T} - y_{d,T} + m_{S,d,T} - m_{S,f,T}.$$

Data:
MS in the U.S. market is expected to increase by 2%. $\Rightarrow m_{S,d,T} = \mathbf{.02}$
All the other variables remain unchanged. $\Rightarrow y_{f,T} = y_{d,T} = m_{S,f,T} = \mathbf{0}$.

$$\Rightarrow s_{t,T} = \mathbf{.02}.$$

$M_{S,d}$ increases **2%** $\Rightarrow S_t$ increases **2%** (depreciation of the USD).

Note: In more complicated monetary approach models, if investors also expect the U.S. Fed to quickly increase i_{US} to avoid inflationary pressures, the USD may appreciate instead of depreciate. ¶

• Monetary Approach: Sticky Prices
There are many variations of the monetary model.

• Popular variation: PPP is not a good short-run theory. We see *sticky prices* (in the short-run).

The sticky prices monetary model incorporates the fact that exchange rates, S_t, are more volatile than domestic prices of goods and services, P_d.

• Short-run reaction to a "*shocks*" –say, a monetary shock
  - Nominal prices (P_d) do not react instantaneously.
  - Financial prices do. Then, S_t *overreacts* (depreciates more than it should in a PPP world) to bring P_d & Q immediately to equilibrium.

• In the long-run, P_d adjusts and S_t appreciates accordingly. The short-run behavior for S_t is called ***overshooting***.

This is a popular model to explain the movement of S_t after financial crisis.

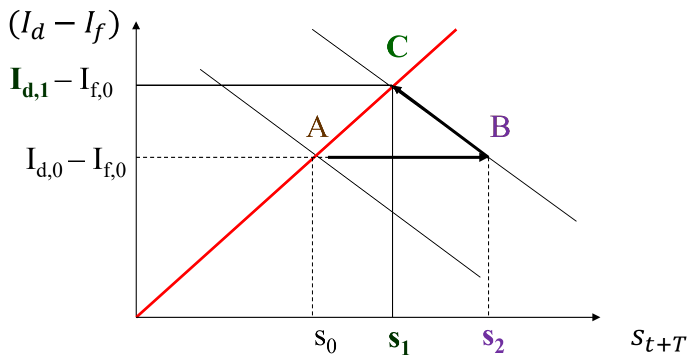
• Monetary Approach: Sticky Prices

• There is a shock in the domestic economy (say, a monetary shock).

• P_d (& I_d) do not react instantaneously. We move from **A** to **B**.

$\Rightarrow I_d$ stays at $I_{d,0}$, but S_t *overreacts* to s_2

• In the long-run, prices will adjust (with higher inflation, $I_{d,1}$) and the exchange rate will move back to s_1.



(3) Portfolio-Balance Approach

It is also part of the Asset Approach of FX determination. Under this approach, the financial assets to be considered by investors are:

- Money: DC & FC
- Bonds: Domestic (DC-denominated) & Foreign (FC-denominated).

Investors' asset preferences may be similar across countries (*uniform preference model)*, or investors may prefer assets of their home country (*preferred local habitat model*).

• S_t is determined to bring equilibrium to the investors' portfolios.

• The balance between DC bonds & FC bonds in a portfolio is positively related to expected excess return on DC bonds over FC bonds.

Example: An **increase** in the supply of DC-denominated bonds or i_f depreciates the DC.

• Structural Models: Evidence

Standard tests of structural models are based on a regression:

$$s_t = \alpha + \beta Z_t + \varepsilon_t$$

where Z_t represents a *structural* explanatory variable: money growth, income growth rates, $(i_d - i_f)$, current accounts, supply of bonds, etc.

Usual results:

– Null hypothesis: H_0: $\beta=0$, is difficult to reject.

– The R^2 tends to be small.

• Many economists say: Structural models are misspecified, because of *structural change*: The model's parameters change with changes in economic policy!

For example, a new Chairman of the Fed may have an effect on the coefficient β. Then, S_t may become more sensitive to $(i_d - i_f)$.

• Structural Models: Evidence

• Event studies analyzing the movement of S_t around news announcements have found some **support** for **structural model** .

• These event studies find that news about:

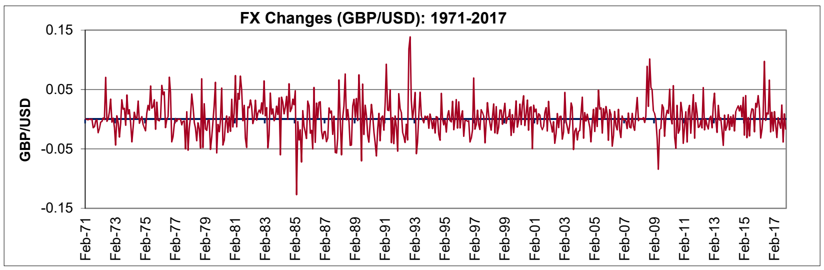
- Greater than expected U.S. CA deficits $\Rightarrow S_t \uparrow$ (BOP approach).
- Unexpected U.S. economic growth $\Rightarrow S_t \downarrow$ (Monetary approach).
- Positive MS surprises $\Rightarrow S_t \downarrow$ (Monetary approach, if Fed is expected to quickly $i_d \uparrow$).
- Unexpected increase of $(i_d - i_f)$ $\Rightarrow S_t \uparrow$ (Monetary approach, sign of MS↑)

• Regression-based structural models do poorly. But, the variables used in structural models tend to have power to explain changes in S_t.

• **Summary**
• **Parity Conditions**
  ◊ **PPP** ⇒ Rejected in the short-run, some long-run support.
  ◊ **IFE** ⇒ Rejected in the short-run, some long-run support.
  ◊ **EH** ⇒ Rejected in the short-run. Puzzle!

• **Structural models**
  ◊ **BOP & Monetary Approach**
⇒ Rejected in the short-run, some support through event studies.

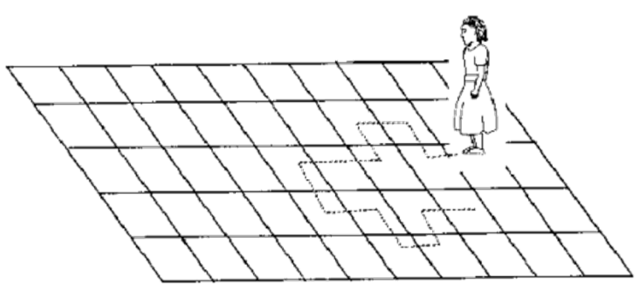
• Q: Why is $s_{t,T}$ so (statistically) difficult to explain?



Martingale-RW Model

The Martingale-Random Walk Model

A **random walk** is a time series **independent** of its own history. Your *last step* has no influence in your *next step*. The past does not help to explain the future.



Motivation: Drunk walking in a park. (Problem posted in *Nature*. Solved by Karl Pearson. July, 1905 issue.)

Very difficult to predict where the drunk will end up after T steps.

Intuitive notion: The FX market is a "*fair game*." (Unpredictable!)

• Martingale-Random Walk Model: Implications

The Random Walk Model (RWM) implies:

$$E_t[S_{t+T}] = S_t.$$

Powerful theory: At time t, all the info about S_{t+T} is summarized by S_t.

Theoretical Justification: Efficient Markets (all available info is incorporated into today's S_t.)

Example: Forecasting with RWM

S_t = 1.60 USD/GBP

$E_t[S_{t+7-day}]$ = **1.60 USD/GBP**

$E_t[S_{t+180-day}]$ = **1.60 USD/GBP**

$E_t[S_{t+10-year}]$ = **1.60 USD/GBP**. ¶

Note: If S_t follows a RW, a firm should spend no resources to forecast S_{t+T}.

• Martingale-Random Walk Model: Evidence

Meese and Rogoff (1983, *Journal of International Economics*) tested the short-run forecasting performance of different models for the four most traded FX rates. They considered economic models (PPP, IFE, Monetary Approach, etc.) and the RWM.

The metric used in the comparison: MSE (mean squared error)

$$\Rightarrow \text{MSE} = \frac{\sum_{t=1}^{Q} \varepsilon_{t+T}^2}{Q} = \frac{\sum_{t=1}^{Q} (S_{t+T} - S_{t+T}^F)^2}{Q}$$

where $\varepsilon_{t+T} = S_{t+T} - S_{t+T}^F$ = forecasting error at horizon T.

⇒ The **RWM** performed *as well as* any other model. Big surprise!

Cheung, Chinn & Pascual (2005) checked M&R's results with 20 more years of data. ⇒ **RWM** still the **best model** in the **short-run**.

M&R started a big literature. In general, M&R's results hold in the short-run (say, up to 6-months), but for longer horizons (say, 1-4 years), models can do better (PPP, IFE and Taylor rule models, individually or combined).

Example: MSE - Forecasting S_t (USD/GBP) with Forwards and the RWM
Data: interest rate differential (in %) and S_t from 2014:II on.
Using IRP, you calculate the forward rate, $F_{t,90}$, and, then, to forecast $E_t[S_{t+90}] = S_{t+90}^F$.

Using the RWM you forecast $E_t[S_{t+90}] = S_t$. Then, to check the accuracy of the forecasts, you calculate the MSE.

Quarter	$(i_{US} - i_{UK})$	S_t	Forward Rate		Random Walk	
			$S_{t+90}^F = F_{t,90}$	$\varepsilon_{t-FR} = S_t - S_t^F$	$S_{t+90}^F = S_t$	$\varepsilon_{t-RW} = S_t - S_t^F$
2014:II	-0.304	**1.6883**				
2014:III	-0.395	**1.6889**	**1.6870**	0.0019	**1.6883**	0.0006
2014:IV	-0.350	**1.5999**	**1.6872**	-0.0873	**1.6889**	-0.0890
2015:I	-0.312	**1.5026**	**1.5985**	-0.0959	**1.5999**	-0.0973
2015:II	-0.415	**1.5328**	**1.5014**	0.0314	**1.5026**	0.0302
2015:III	-0.495	**1.5634**	**1.5312**	0.0322	**1.5328**	0.0306
2015:IV		**1.5445**	**1.5615**	-0.0170	**1.5634**	-0.0189
MSE				**0.04427**		**0.04443**

Both MSEs are similar, though the $F_{t,T}$'s MSE is a bit smaller (.4% lower). ¶

• Martingale-Random Walk Model: Empirical Models Trying to Compete

Models of FX rates determination based on fundamentals not very good at explaining (& forecasting) S_t, especially in the short-run.

Many empirical models developed to better explain *equilibrium exchange rates* (EERs).

Some models are built to explain the medium- or long-run behavior of S_t, others are built to beat the forecasting performance of the RWM.

A short list of the new models includes CHEERs, ITMEERs, BEERs, PEERs, FEERs, APEERs, PEERs, and NATREX.

	UIP	PPP	Balassa-Samuelson	Monetary Models	CHEERs	ITMEERs	BEERs
Name	Uncovered Interest Parity	Purchasing Power Parity	Balassa-Samuelson	Monetary and Portfolio balance models	Capital Enhanced Equilibrium Exchange Rates	Intermediate Term Model Based Equilibrium Exchange Rates	Behavioural Equilibrium Exchange Rates
Theoretical Assumptions	The expected change in the exchange rate determined by interest differentials	Constant Equilibrium Exchange Rate	PPP for tradable goods. Productivity differentials between traded and nontraded goods	PPP in long run (or short run) plus demand for money.	PPP plus nominal UIP without risk premia	Nominal UIP including a risk premia plus expected future movements in real exchange rates determined by fundamentals	Real UIP with a risk premia and/or expected future movements in real exchange rates determined by fundamentals
Relevant Time Horizon	Short run	Long run	Long run	Short run	Short run (forecast)	Short run (forecast)	Short run (also forecast)
Statistical Assumptions	Stationarity (of change)	Stationary	Non-stationary	Non-stationary	Stationary, with emphasis on speed of convergence	None	Non-stationary
Dependent Variable	Expected change in the real or nominal	Real or nominal	Real	Nominal	Nominal	Future change in the Nominal	Real
Estimation Method	Direct	Test for stationarity	Direct	Direct	Direct	Direct	Direct

FEERs	DEERs	APEERs	PEERs	NATREX	SVARs	DSGE
Fundamental Equilibrium Exchange Rates	Desired Equilibrium Exchange Rates	Atheoretical Permanent Equilibrium Exchange Rates	Permanent Equilibrium Exchange Rates	Natural Real Exchange Rates	Structural Vector Auto Regression	Dynamic Stochastic General Equilibrium models
Real exchange rate compatible with both internal and external balance. Flow not full stock equilibrium	As with FEERs, but the definition of external balance based on *optimal* policy	None	As BEERs	As with FEERs, but with the assumption of portfolio balance (so domestic real interest rate is equal to the world rate).	Real exchange rate affected by supply and demand (but not nominal) shocks in the long run	Models designed to explore movements in real and/or nominal exchange rates in response to shocks.
Medium run	Medium Run	Medium / Long run	Medium / Long run	Long run	Short (and long) run	Short and long run
Non-stationary	Non-stationary	Non-stationary (extract permanent component)	Non-stationary (extract permanent component)	Non-stationary	As with theoretical	As with theoretical
Real Effective	Real Effective	Real	Real	Real	Change in the Real	Change relative to long run steady state
Underlying Balance	Underlying Balance	Direct	Direct	Direct	Direct	Simulation

• Recent Models

• Overall, a negative message for short-time forecasters. The RWM does very well in the short-run, especially, 1-3 months.

• Recent literature focuses on building factor models for S_t, similar to the factor models used for equity & bond markets. For example, Verdelhan (2018) presents the following model for FC j:

$$s_{j,t+1} = \alpha_j + \beta_j\ Dollar_{t+1} + \tau_i(i_{j,t} - i_t) + \delta_j\ Carry_{t+1} + \gamma_j(i_{j,t} - i_t) * Carry_{t+1} + \varepsilon_{j,t+1}$$

with the following factors:

Dollar: Average change in the value of FCs. Plays the role of the "*Market*."

Interest rate differential: Return from lending at i_j & borrowing at i_t (USD).

Carry: Average change in FX rates of high- vs low-interest rate FCs.

Conditional factor: Interaction term: $(i_{j,t} - i_t) * Carry_{t+1}$

• **Factors:**

• **Dollar:** Average change in the value of foreign currencies, in terms of USD.

$$Dollar_{t+1} = \frac{1}{N}\sum_j s_{j,t+1}$$

• **Interest rate differential:** Return from investing at foreign interest rate & borrowing at USD interest rate. In equilibrium, using IRP:

$$f_{j,t} - s_{j,t} \approx i_{j,t} - i_t$$

• **Carry factor:** Average change in FX rates of high-interest rate (*H*) versus FX rates of low-interest rate (*L*) currencies.

$$Carry_{t+1} = \frac{1}{N_H}\sum_{j\in H} s_{j,t+1} - \frac{1}{N_L}\sum_{i\in L} s_{j,t+1}$$

• **Conditional factor:** Interaction term: $(i_{j,t} - i_t) * Carry_{t+1}$

Forecasting Exchange Rates

Model Needed

A forecast needs a model, which specifies a **function** for S_t:

$$S_t = f(X_t)$$

• The model needs a **functional form** and a set of **driving variables**, X_t.

◊ Functional form, $f(X_t)$: In this class, **linear**

◊ Driving variables, X_t, can be based on

- Economic Theory (say, PPP: $X_t = I_d - I_f \Rightarrow f(X_t) = I_{d,t} - I_{f,t}$
- Technical Analysis (say, past trends)
- Statistics
- Experience of forecaster
- Combination of all of the above

Forecasting: Basics

• A forecast is an **expectation** –i.e., what we expect on average:

$E_t[S_{t+T}]$ ⇒ Expectation of S_{t+T} taken at time t ("*today*").

• Easier to predict changes ⇒ $E_t[s_{t+T}]$.

Note: From $E_t[s_{t+T}]$, we get $E_t[S_{t+T}]$ ⇒ $E_t[S_{t+T}] = S_t * (1+E_t[s_{t+T}])$

• Based on a model for S_t, we generate $E_t[S_{t+T}]$:

$S_t = f(X_t)$ ⇒ $E_t[S_{t+T}] = E_t[f(X_{t+T})]$

Assumptions needed for X_{t+T}

Today, we do not know X_{t+T}. We will make **assumptions** to get X_{t+T}.

Example: $X_{t+T} = h(Z_t)$, –Z_t: Data available today.

⇒ We'll use Z_t to forecast the future S_{t+T}: $E_t[S_{t+T}] = g(Z_t)$

Example: What is $g(Z_t)$?

Using PPP, we forecast USD/GBP changes one period ahead (T=1):

1. Model for S_t

$$E_t[s_{t+1}] = s^F_{t+1} = \frac{S^F_{t+1}}{S_t} - 1 \approx I_{d,t+1} - I_{f,t+1}$$

Now, once we have s^F_{t+1}, we can forecast the level S_{t+1}

$$E_t[S_{t+1}] = S_t * [1 + s^F_{t+1}] = S_t * [1 + (I_{US,t+1} - I_{UK,t+1})]$$

2. Assumption for I_{t+1} ⇒ $I_{t+1} = h(Z_t)$

- $I_{US,t+1} = \alpha_0^{US} + \alpha_1^{US} I_{US,t}$
- $I_{UK,t+1} = \alpha_0^{UK} + \alpha_1^{UK} I_{UK,t}$

3. $E_t[S_{t+1}] = g(Z_t)$

- $E_t[S_{t+1}] = g(I_{US,t}, I_{UK,t})$

$$= S_t * [1 + \alpha_0^{US} + \alpha_1^{US} I_{US,t} - \alpha_0^{UK} - \alpha_1^{UK} I_{UK,t}]$$

• There are two forecasts: *in-sample* and *out-of-sample*.

- *In-sample*: It uses sample info to forecast sample values. Not really forecasting, it can be used to evaluate the fit of a model.
- *Out-of-sample*: It uses the sample info to forecast values outside the sample. In time series, it forecasts into the future.

Two Pure Approaches to Forecasting

Based on the "driving" variables X_t, we have:

- Fundamental Approach, based on data considered *fundamental*.
- Technical Analysis or TA, based on data that incorporates only past prices: P_{t-1}, P_{t-2}, P_{t-3}, ...

Fundamental Approach

Economic Model

Generate $E_t[S_{t+T}] = E_t[f(X_{t+T})] = g(X_t)$, where X_t is a dataset of *fundamental* economic variables:

- GNP growth rate,
- Current Account,
- Interest rates,
- Inflation rates, etc.

• **Fundamental variables**: Taken from *economic models* (PPP, IFE, etc.)

⇒ The model says how the fundamental data relates to S_t.

That is, the model specifies $f(X_t)$ –for PPP, $f(X_t) = I_{d,t} - I_{f,t}$

- The model, $f(X_t)$, usually incorporates:
  - **Statistical characteristics** of the data
  - **Experience** of the forecaster

    ⇒ Mixture of **art** and s**cience**.

Fundamental Forecasting: Steps

(1) Selection of Model (say, PPP model).

(2) Get Data: S_t & X_t (for PPP: S_t & CPI data.)

(3) Estimation of model, if needed.

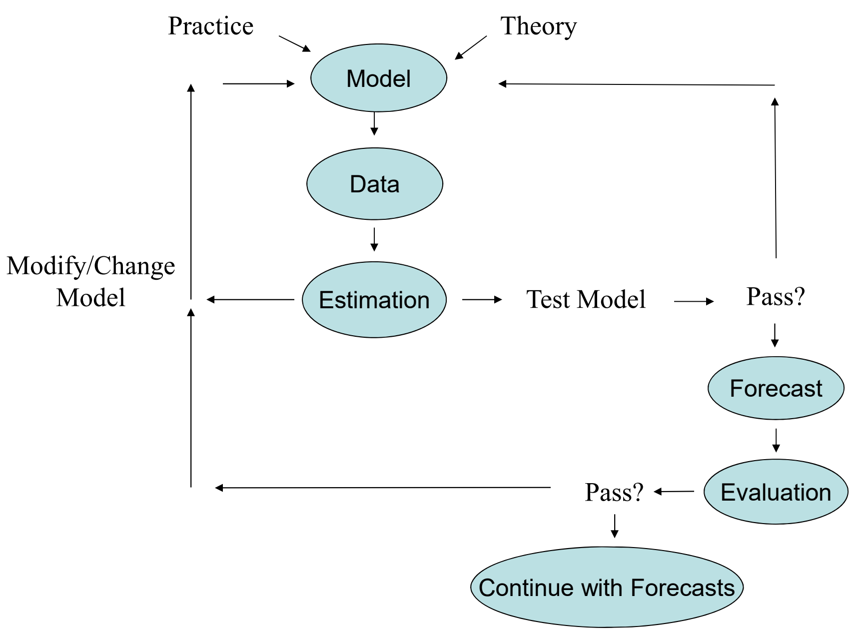
(4) Generation of forecasts. Assumptions about X_{t+T} may be needed.

(5) Evaluation of forecasts. If forecasts are bad, model must be changed. Popular evaluation metrics:

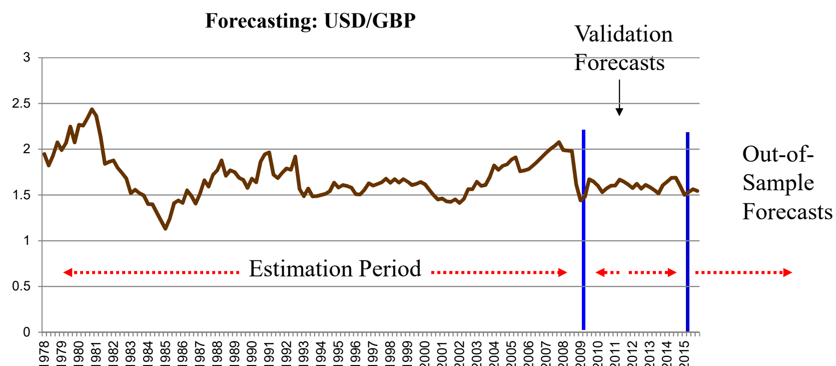
⇒ MSE (Mean Square Error) $= \frac{\sum_{J=1}^{Q}(S_{t+J}-S_{t+J}^{F})^2}{Q}$

⇒ MAE (Mean Absolute Error) $= \frac{\sum_{J=1}^{Q}|S_{t+J}-S_{t+J}^{F}|}{Q}$

Fundamental Forecasting: Process for Building Forecasting Model



Fundamental Forecasting: Usual Estimation Process



1) Select a (long) part of the sample to estimate the parameters of the selected model. This is the *estimation step*.

2) Keep a (short) part of the sample to check the model's forecasting skills. This is the *validation step*. You can calculate true MSE or MAE

3) If happy with model from 1) & 2), forecast **out-of-sample**.

Fundamental Forecasting: Usual Estimation Process

Note: In the Machine Learning literature, the terminology used for the process to select a forecasting model is slightly different.

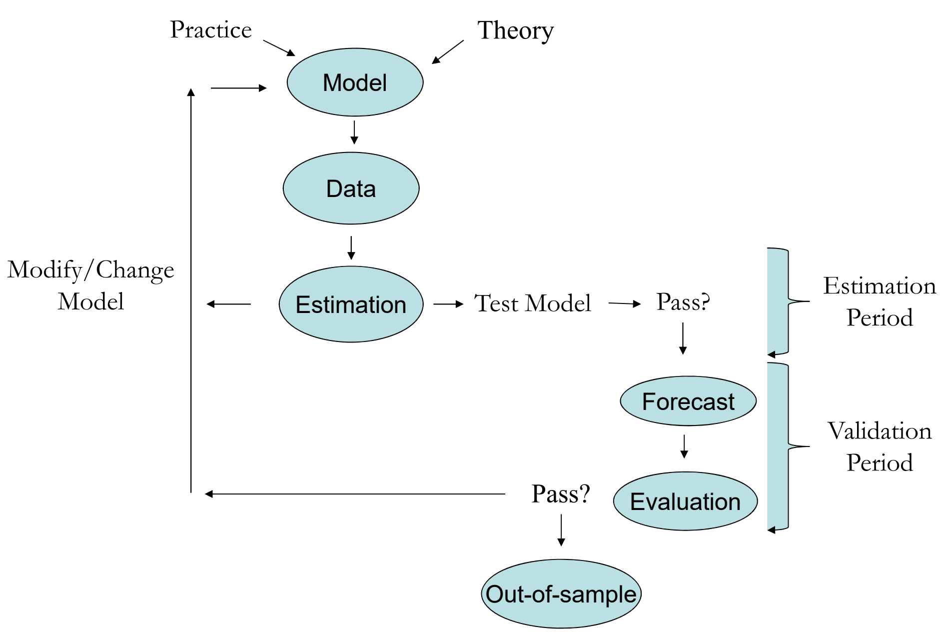
Step 1 is called *training step,* the data used (say, first T_1 observations) are called *training data/set*. In this step, we **estimate** the parameters of the model subject to assumptions, for example, PPP or Monetary Approach.

Step 2 has the same name, the *validation step*. This step is used to "*tune (hyper)parameters*." In our simple linear model, we **tune** by including more variables in the driving set X_t and re-estimating the model accordingly, using the "training data" alone. We choose the model with lower MSE or MAE

Remark: The idea of this step is to **simulate** out-of-sample accuracy. But, the "tuned" parameters selected in Step 2 are fed back to Step 1.

Step 3 tests the true out-of-sample forecast accuracy of the model selected by **Step 1** & **Step 2**. This last part of the sample is called "*testing sample*."

Out-of-Sample Forecasting: Estimation and Validation Period



Example: *In-sample* PPP forecasting of USD/GBP

Model: Relative PPP. Then, the formula for USD/GBP changes:

$$E_t[s_{t+1}] = s^F_{t+1} \approx I_{US,t+1} - I_{UK,t+1} \quad \Rightarrow E_t[S_{t+1}] = S^F_{t+1} = S_t * [1 + s^F_{t+1}]$$

Data: Quarterly CPI series for U.S. and U.K. from 1996:1 to 1997:3.

$P_{d=US}$: (1996:1, 1996:2) US-CPI: 149.4, 150.2

$P_{f=UK}$: (1996:1, 1996:2) UK-CPI: 167.4, 170.0

$S_{1996:1}$ = 1.5262 USD/GBP.

$S_{1996:2}$ = **1.5529 USD/GBP**.

1. Forecast $S^F_{1996:2} = f(X_{t=1996:2})$

$I_{US,1996:2}$ = ($USCPI_{1996:2}/USCPI_{1996:1}$) – 1 = (150.2/149.4) – 1 = **.00535**.

$I_{UK,1996:2}$ = ($UKCPI_{1996:2}/UKCPI_{1996:1}$) – 1 = (170.0/167.4) – 1 = .01553

$s^F_{1996:2} = I_{US,1996:2} - I_{UK,1996:2}$ = **.00535** – .01553 = **-.01018**.

$S^F_{1996:2} = S^F_{1996:1} * [1 + s^F_{1996:2}]$ = **1.5262 USD/GBP** * [1 + (**-.01018**)] =
= **1.5107** USD/GBP.

- **Example (continuation)**: *In-sample* PPP forecasting

$S^F_{1996:2}$ = **1.5107** USD/GBP.

2. Forecast evaluation (Forecast error: $S^F_{1996:2} - S_{1996:2}$)

$\varepsilon_{1996:2} = S^F_{1996:2} - S_{1996:2}$ = **1.5107** – **1.5529** = -0.0422.

For the whole sample:

Date	CPI U.S.	CPI U.K.	In-Sample Forecast (S^F_{t+1})	Actual (S_t)	Forecast Error $\varepsilon_{t+1}=S^F_{t+1}-S_{t+1}$
1996:1	149.4	167.4	1.5262	1.5262	-
1996:2	150.2	170.0	1.5107	1.5529	-0.0422
1996:3	151.3	170.4	1.5182	1.5653	-0.0471
1996:4	152.6	171.5	1.5214	1.7123	-0.1909
1997:1	153.2	173.3	1.5114	1.6448	-0.1334
1997:2	154.1	176.0	1.4968	1.6650	-0.1682
1997:3	155.6	179.0	1.4858	1.6117	-0.1259

MSE: $[(-0.0422)^2 + (-0.0471)^2 + ... + (-0.1259)^2]/6$ = **0.017063278**

Note: Not true forecasting: At time t, I_{t+1} is unknown. We need $E_t[I_t]$.

Example 1: *Out-of-sample* Forecast: $E_t[S_{t+1}] = f(X_t)$

• Simple forecasting model: Naive forecast ($E_t[I_{t+1}] = I_t$)

$E_t[s_{t+1}] = s^F_{t+1} = (E_t[S_{t+1}]/S_t) - 1 \approx I_{d,t} - I_{f,t}$

Using the above information we can predict $S_{1996:3}$:

1. Forecast $S^F_{1996:3}$

$s^F_{1996:3} = I_{US,1996:2} - I_{UK,1996:2} = .00535 - .01553 = -0.01018.$

$S^F_{1996:3} = S_{1996:2} * [1 + s^F_{1996:3}] = 1.5529 * [1 + (-0.01018)] = 1.53709$

2. Forecast Evaluation

$\varepsilon_{1996:3} = S^F_{1996:3} - S_{1996:3} = 1.53709 - 1.5653 = -0.028210.$

More sophisticated forecasts using models for I, survey data on expectations of I, etc.

Example 1A: AR(1) model for inflation,

$I_{US,t+1} = \alpha_0^{US} + \alpha_1^{US} I_{US,t} + \varepsilon_{US,t+1}.$

$I_{UK,t+1} = \alpha_0^{UK} + \alpha_1^{UK} I_{UK,t} + \varepsilon_{UK,t+1}.$

Suppose we estimate both equations. The estimated coefficients (a's) are:

$a_0^{US} = .0036$, $a_1^{US} = .64$, $a_0^{UK} = .0069$, & $a_1^{UK} = .43$.

$\Rightarrow I^F_{US,1996:3} = .0036 + .64 * (.00535) = .007024$

$\Rightarrow I^F_{UK,1996:3} = .0069 + .43 * (.01553) = .013578.$

$s^F_{1996:3} = I^F_{US,1996:3} - I^F_{UK,1996:3} = .007024 - .013578 = -.00655.$

$S^F_{1996:3} = 1.5529\ USD/GBP * [1 + (-.00655)] = 1.5427\ USD/GBP.$

$\varepsilon_{1996:3} = S^F_{1996:3} - S_{1996:3} = 1.5427 - 1.5653 = -0.0226.$

Example 1A (continuation): Exchange Rate Forecasts

US Excel Regression Results for US Inflation Forecasts ($I_{US,t+1}$):

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.629674
R Square	0.396489
Adjusted R Square	0.391583
Standard Error	0.006811
Observations	125

← How much variability of Y_t is explained by X_t

t-stat tests H_o: $a_i=0$

$t_{a1}=a_1/SE(a_1)=$ **0.640707**/**0.071274**=**8.9893**

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.003748	0.003748	80.80752	3.66E-15
Residual	123	0.005705	4.64E-05		
Total	124	0.009454			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	**0.00366**	**0.000923**	**3.965867**	0.000123
X Variable 1	**0.640707**	**0.071274**	**8.9893**	3.66E-15

Example 1A (continuation): $I_{UK,t+1}$ - UK Regression Results:

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.425407
R Square	0.180971
Adjusted R Square	0.174312
Standard Error	0.011305
Observations	125

← $I_{UK,t-1}$ explains 18.10% of the variability of $I_{UK,t}$

t-stat is significant at the 5% level (|t|>1.96)

=> Lagged Inflation explains current Inflation

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.003473	0.003473	27.17784	7.6E-07
Residual	123	0.015719	0.000128		
Total	124	0.019192			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	**0.006918**	**0.001403**	**4.932637**	2.57E-06
X Variable 1	**0.428132**	**0.082124**	**5.213237**	7.6E-07

Example 2: *Out-of-sample* Forecasting FX with an Ad-hoc Model

Forecast monthly MYR/USD changes with the following model:

$$s_{MYR/USD,t} = a_0 + a_1 (I_{MYR} - I_{USD})_t + a_2 (y_{MYR} - y_{USD})_t + \varepsilon_t$$

Excel Regression Results:

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.092703
R Square	0.018594
Adjusted R Square	-0.0087
Standard Error	0.051729
Observations	112

← X_t explains 1.86% of the variability of s_t

t-stat tests $H_o: \alpha_i = 0$

$t_{a1} = a_1/SE(a_1)$ = **0.215927**/**0.105824** = **2.040435**

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.002528	0.001264	0.47242	0.624762
Residual	109	0.291666	0.002676		
Total	111	0.294195			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	**0.006934**	**0.005175**	**1.339903**	0.180277
X Variable 1 $(I_{MYR} - I_{USD})_t$	**0.215927**	**0.105824**	**2.040435**	0.041307
X Variable 2 $(y_{MYR} - y_{USD})_t$	**0.091592**	**0.051676**	**1.772428**	0.076326

Example 2 (continuation): Out-of-sample Forecasting w/Ad-hoc Model

$$s_{MYR/USD,t} = a_0 + a_1 (I_{MYR} - I_{USD})_t + a_2 (y_{MYR} - y_{USD})_t + \varepsilon_t$$

0. Model Evaluation

Estimated coefficient: a_0 = **.0069**, a_1 = **.2159**, and a_2 = **.0915**.

t-stats: t_{a1}=|2.040435| **> 1.96 (reject H_0) ;** t_{a2}=|1. 772428| **< 1.96 (can't reject H_0)**

Do the signs make sense? a_1 = **.2159** > 0 ⇒ PPP

a_2 = **.0915** > 0 ⇒ Trade Balance

1. Forecast S^F_{t+1}

$E[s_{MYR/USD,t}]$ = **.0069** + **.2159** $(I_{MYR} - I_{USD})_t$ + **.0915** $(y_{MYR} - y_{USD})_t$

Forecasts for next month (t+1): $E_t[INF_{t+1}]$ = 3% & $E_t[INC_{t+1}]$ = 2%.

$E_t[s_{MYR/USD,t+1}]$ = **.0069** + **.2159** * (.03) + **.09157** * (.02) = **.0152**.

The MYR is predicted to depreciate **1.52%** against the USD next month.

Example 2 (continuation): Out-of-sample Forecasting w/Ad-hoc Model

1. Forecast S^F_{t+1} (continuation)

$E_t[s_{MYR/USD,t+1}]$ = **.0152**.

Suppose S_t = **3.1021 MYR/USD**

S^F_{t+1} = **3.1021 MYR/USD** * (1 + **.0152**) = **3.1493** MYR/USD.

2. Forecast Evaluation

Suppose S_{t+1} = **3.0670** MYR/USD.

$\varepsilon_{t+1} = S^F_{t+1} - S_{t+1}$ = **3.1493** – **3.0670** = 0.0823. ¶

• Practical Issues in Fundamental Forecasting

Issues:

- Are we using the "*right model*"?
- Estimation of the model.
- Some explanatory variables (Z_{t+T}) are contemporaneous.
  - ⇒ We also need a model to forecast the Z_{t+T} variables.

• Does Forecasting Work?

RW models beat structural (and other) models: Lower MSE, MAE.

• Right Evaluation Metric?

Richard Levich compared forecasting services to the free forward rate. He found that forecasting services may have some ability to predict direction (appreciation or depreciation).

For some investors, the direction is what really matters, not the error.

Example: Two forecasts: Forward Rate and Forecasting Service (FS)

$F_{t,1\text{-month}}$ = .7335 USD/CAD

$E_{FS,t}[S_{t+1-mo}]$= **.7342 USD/CAD**.

• Sternin's strategy: Buy CAD forward if FS forecasts > $F_{t,1\text{-month}}$.

Based on the FS forecast, Sternin buys CAD forward at $F_{t,1\text{-month}}$ = .7335.

(A) Suppose that S_{t+1-mo} = **.7390 USD/CAD**.

MAE_{FS} = | **.7390** – **.7342** | = .0052 USD/CAD.

Sternin makes a profit: **.7390** – .7335 = .055 USD/CAD.

(B) Suppose that S_{t+1-mo} = **.7315 USD/CAD**.

MAE_{FS} = | **.7315** – **.7342** | = .0027 USD/CAD (smaller!)

Sternin takes a loss: **.7315** – .7335 = -.0020 USD/CAD. ¶

Remark: Getting direction right is more important. Different metric?

Technical Analysis Approach

• Based on a small set of the available data: Past price information.

Q: Why ignore fundamentals, say, $(I_{d,t} - I_{f,t})$?

EMH: FX market "discounts" public information regarding fundamentals

• TA looks for the repetition of specific price patterns.

• TA attempts to generate signals: trends and turning points.

• TA models range from very simple (say, looking at price charts) or very sophisticated, incorporating neural networks and genetic algorithms.

• Popular TA models:
  - Moving Averages (MA)
  - Filters
  - Momentum indicators.
  - Bollinger Bands (MA + SD, used to create "bands" for MA)
  - Relative Strength Index, RSI (it determines "over/under-sold")
  - Fibonacci Retracements, "Fibs" (Fibonacci ratios determine potential retracements from a high).

• We will review the first three models: MA, Filters and Momentum.

(1) *MA models*

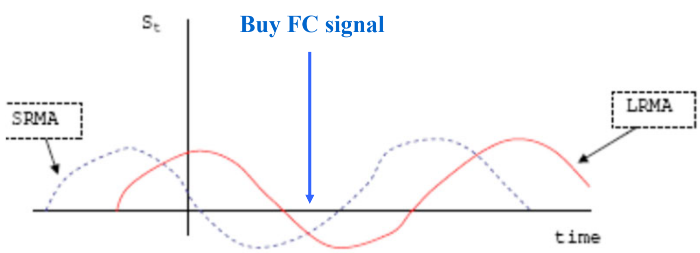
MA model: Smooth erratic daily swings of S_t.

Define S_t^{MA} as SMA:

$$S_t^{MA} = (S_t + S_{t-1} + S_{t-2} + \ldots + S_{t-(Q-1)})/Q$$

Double MA system uses two S_t^{MA}'s: Long-run MA, with Q=Q_L & Short-run MA, with Q = Q_S, $Q_L > Q_S$.

LRMA always lag a SRMA (gives smaller weights to recent S_t).



Buy FC signal: When SRMA crosses LRMA from below.
Sell FC signal: When SRMA crosses LRMA from above.

Example: S_t (USD/GBP) Double MA - Q_S=30 days (red); & Q_L=150 days (green).

(2) *Filter models*

Filter = **X**, a *percentage* that helps to spot a trend.

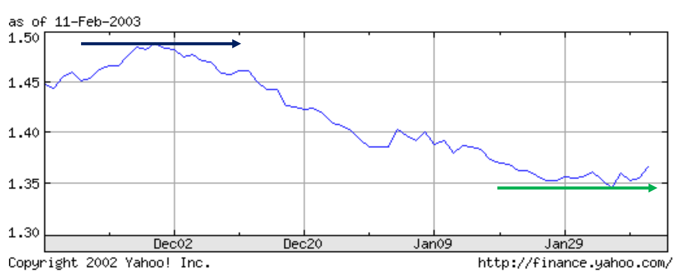
Sell signal: S_t falls **X%** below the previous peak.

Buy signal: S_t rises **X%** above its most recent trough.

Idea:

When S_t reaches a peak ⇒ Sell FC

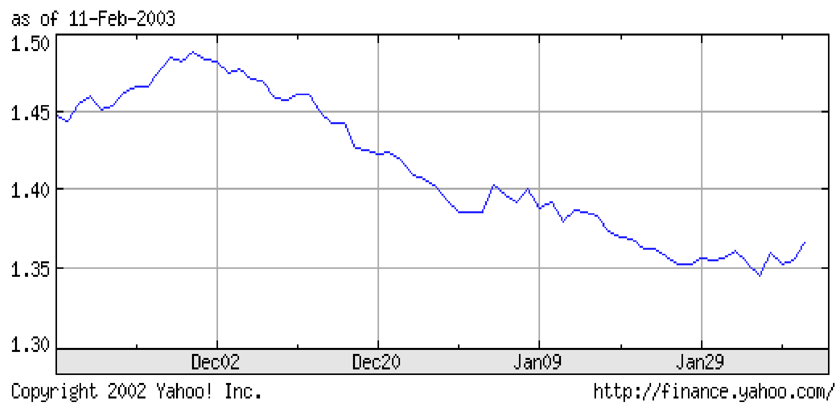
When S_t reaches a trough ⇒ Buy FC.



Key: Identifying a peak/trough. The filter does it:

When S_t moves **X%** above (below) its most recent high (low), we have identified a peak (through).

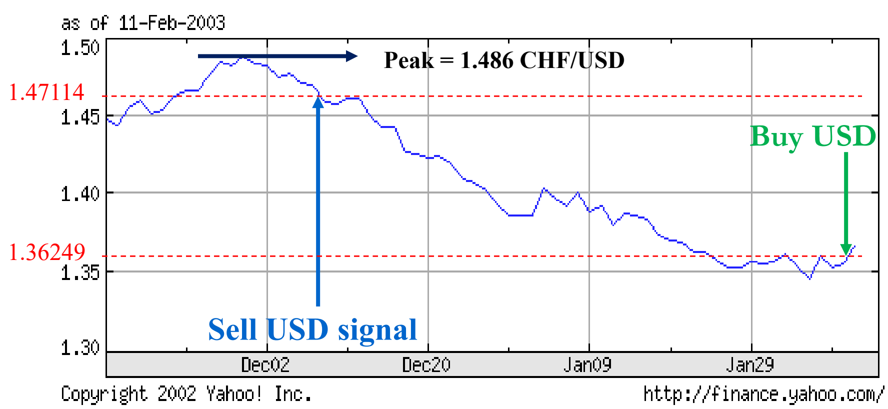
Example: X = 1%, S_t (CHF/USD)



Peak = 1.486 CHF/USD (X = CHF .01486)
⇒ When S_t crosses 1.47114 CHF/USD, **Sell USD**

Trough = 1.349 CHF/USD (X = CHF .01349)
⇒ When S_t crosses 1.36249 CHF/USD, **Buy USD**

Example: X = 1%, S_t (CHF/USD)



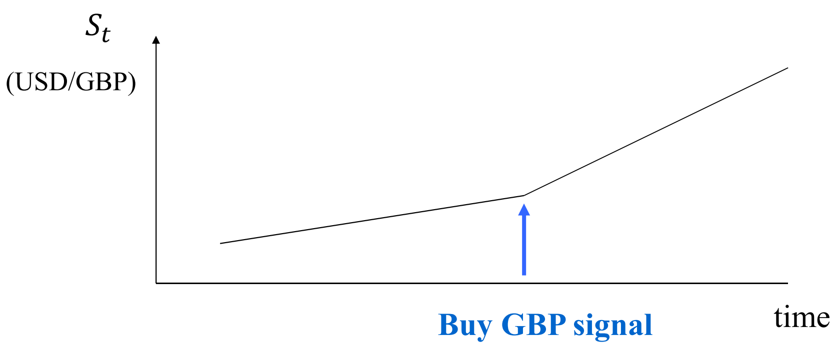
Peak = 1.486 CHF/USD (X = CHF .01486)
⇒ When S_t crosses 1.47114 CHF/USD, **Sell USD**

(3) *Momentum models*

They determine the strength of an asset by examining the change in velocity of asset prices' movements.

We are looking at the second derivative (a change in the slope).

Buy signal: When S_t climbs at increasing speed.
Sell signal: When S_t decreases at increasing speed.



• TA Newer Models:

In MA and filter models, we need to select a parameter (Q & X). Subjective selection: Two TA practitioners using the same model may generate different signals.

Newer TA methods rely on more sophisticated formulas to determine when to buy/sell, without the subjective selection of parameters.

Clements (2010, *Technical Analysis in FX Markets*) describes four of these methods: Relative strength indicator (RSI), Exponentially weighted moving average (EWMA), Moving average convergence divergence (MACD) and (iv) Rate of change (ROC).

• TA Summary:

TA models monitor the derivative (slope) of a time series graph. Signals are generated when the slope varies significantly.

• **Technical Approach: Evidence**

- *Against TA:*

• RW model: A good forecasting model.

• Economists have a negative view of TA: TA runs against EMH.

- *For TA:*

• Informal evidence: FX Mkt is full of TA newsletters & traders (30%).

• Formal (academic) support:

  ∘ In general, in-sample results tend to be good (profitable). But, not out-of-sample.

  ∘ LeBaron (1999): Apparent success of TA in FX markets is influenced by CB intervention.

  ∘ Lo (2004): Markets are adaptive efficient: TA may work for a while.

  ∘ Ohlson (2004): Even in-sample, profitability has declined (≈ 0 profits by the 1990s).

  ∘ Park and Irwin (2007): Problems with TA studies: Data snooping, ex-post selection of trading rules, estimation of risk & transaction costs.

CASE 1 – FX Forecasting

• Two parts – **Group assignment** (Mr Ritz's job)

– **Class assignment**

• **Group assignment**

• Mr. Ritz wants to forecast FX rates from **2021:IV – 2022:III** with:

(a) PPP.

(b) Forward exchange rates.

(c) Monetary approach.

(d) Ad-hoc economic models.

• Data: Quarterly FX Rates from **1978:I** – **2022:IV** for GBP, JPY, MXN, & KOW

- Estimate the models using data up to **2019:III**. Evaluate *in-sample* results (t-stats & R^2).

- Forecast **2019:IV - 2022:IV**. Evaluate *out-of-sample* results with MSE.

- Forecast **2019:IV - 2022:IV** using RWM. Evaluate forecasts with MSE.

- For each currency, select the "best" model –i.e., lowest MSE. Forecast **2023:I**.

- **Class assignment**

Ad-hoc Model: $s_{t,T} = \alpha + ß_1 (I_{d,t} - I_{f,t}) + ß_2 (i_{d,t} - i_{f,t}) + ß_3 (y_{d,t} - y_{f,t}) + \varepsilon_t$

Estimate Model for USD/GBP, using whole sample: **1978:II - 2020:III**.

1) Do the signs make sense?

2) Evaluate model with t-stats and R^2.

3) a. Estimate model with data up **2021:III**. (Estimation period: **1978:II - 2021:III**.)
   b. Generate forecasts for **2021:IV** to **2022:IV**.

4) Compute MAE for forecasts

5) Compute Forward Rates using IRP formula for **2021:IV** to **2022:IV**. Use forward rate as a forecast. Compute MAE.

6) Briefly discuss success/failure of model.

