IFE, EH & RW

International Fisher Effect (IFE)

- IFE builds on the law of one price, but for financial transactions.
- Idea: The return to international investors who invest in money markets in their home country should be equal to the return they would get if they invest in foreign money markets once adjusted for currency fluctuations.
- Exchange rates will be set in such a way that international investors cannot profit from interest rate differentials --i.e., no profits from *carry trades*.

The "effective" T-day return on a foreign bank deposit is:

$$r_d\ (f) = (1 + i_f \text{ x } T/360)\ (1 + s_T)\ \text{-}1.$$

- While, the effective T-day return on a home bank deposit is:

$$r_d\ (d) = i_d \text{ x } T/360.$$

- Setting r_d (d) = r_d (f) and solving for $e_{f,T} = (S_{t+T}/S_t - 1)$ we get:

$$e^{IFE}_{f,T} = \frac{(1 + i_d \text{ x } T/360)}{(1 + i_f \text{ x } T/360)} - 1. \qquad \text{(This is the IFE)}$$

- Using a linear approximation: $e^{IFE}_{f,T} \approx (i_d - i_f) \text{ x } T/360.$

- $e^{IFE}_{f,T}$ represents an expectation. It's the expected change in S_t from t to t+T that makes looking for the "extra yield" in international money markets not profitable.

• Since IFE gives us an expectation for a future exchange rate –S_{t+T}-, if we believe in IFE we can use this expectation as a forecast.

Example: Forecasting S_t using IFE.

It's 2011:I. You have the following information:

$S_{2011:I}$ = 1.0659 USD/EUR.

$i_{USD,2011:I}$ = 6.5%

$i_{EUR,2011:I}$ = 5.0%.

T = 1 quarter = 90 days.

$e^{IFE}_{f,,2011:II}$ = [1+ $i_{USD,2011:I}$ x (T/360)]/[1+ $i_{EUR,2011:I}$ x (T/360)] – 1 =
= [1+.065*(90/360))/[1+.05*(90/360)] – 1 = **0.003704**

E[$S_{2011:II}$] = $S_{2011:I}$ x (1+$e^{IFE}_{f,,2011:II}$) = **1.659 USD/EUR** *(1 + **.003704**)
= **1.06985 USD/EUR**

That is, next quarter, you expect S_t to change **1.06985 USD/EUR** to compensate for the higher U.S. interest rates. ¶

• <u>Note</u>: Like PPP, IFE also gives an *equilibrium* exchange rate. Equilibrium will be reached when there is no capital flows from one country to another to take advantage of interest rate differentials.

<u>IFE: Implications</u>

If IFE holds, the expected cost of borrowing funds is identical across currencies. Also, the expected return of lending is identical across currencies.

Carry trades –i.e., borrowing a low interest currency to invest in a high interest currency- should not be profitable.

If departures from IFE are consistent, investors can profit from them.

Example: Mexican peso depreciated 5% a year during the early 90s.

Annual interest rate differential (i_{MEX} - i_{USD}) were between 7% and 16%.

The $E[e_{f,T}]$= -5% > $e^{IFE}_{f,T}$ = -7% $\Rightarrow$ Pseudo-arbitrage is possible
(The MXN at t+T is overvalued!)

Carry Trade Strategy:

1) Borrow USD funds (at i_{USD})
2) Convert to MXN at S_t
3) Invest in Mexican funds (at i_{MEX})
4) *Wait* until T. Then, convert back to USD at S_{t+T}.

Expected foreign exchange loss 5% ($E[e_{f,T}]$= -5%)

Assume (i_{USD} – i_{MXN}) = -7%. (Say, i_{USD}= 5%, i_{MXN}=12%.)

$E[e_{f,T}]$= -5% > $e^{IFE}_{f,T}$ =-7% $\Rightarrow$ "on average" strategy (1)-(4) should work.

Example (continuation):

Expected return (MXN investment):

r_d (f) = $(1 + i_{MXN} x T/360)(1 + s_T) - 1 = (1.12)*(1-.05) - 1 = 0.064$

Payment for USD borrowing:

r_d (d) = i_d x T/360 = .05

Expected Profit = .014 per year

- Overall expected profits ranged from: 1.4% to 11%.

Note: Fidelity used this uncovered strategy during the early 90s. In Dec. 94, after the Tequila devaluation of the MXN against the USD, lost everything it gained before. Not surprised, after all the strategy is a "pseudo-arbitrage" strategy! ¶

- You may have noticed that IFE pseudo-arbitrage strategy differs from covered arbitrage in the final step. Step 4) involves no coverage.

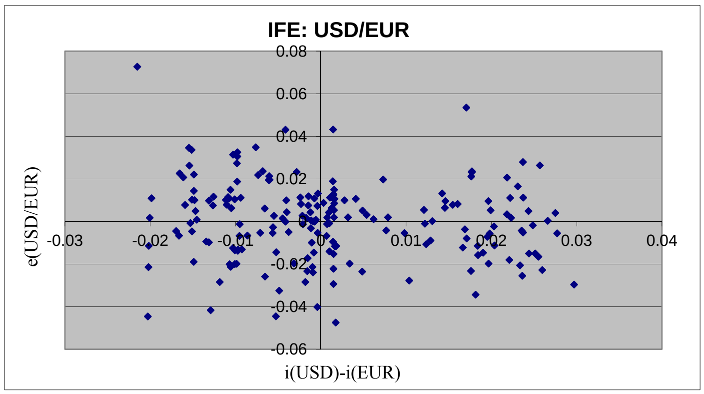
- It's an *uncovered* strategy. IFE is also called Uncovered Interest Rate Parity (UIRP).

1. Visual evidence.

Based on linearized IFE: $e_{f,T} \approx (i_d - i_f) \times T/360$

Expect a 45 degree line in a plot of $e_{f,T}$ against $(i_d - i_f)$

Example: Plot for the monthly USD/EUR exchange rate (1999-2015)



No 45° line $\Rightarrow$ Visual evidence rejects IFE. ¶

2. Regression evidence

$$e_{f,T} = (S_{t+T} - S_t)/S_t = \alpha + \beta\,(i_d - i_f)_t + \varepsilon_t, \quad (\varepsilon_t \text{ error term, } E[\varepsilon_t]=0).$$

- The null hypothesis is: H_0 (IFE true): $\alpha=0$ and $\beta=1$

  H_0 (IFE not true): $\alpha\neq0$ and/or $\beta\neq1$

Example: Testing IFE for the USD/EUR with monthly data (1999-2015).

$R^2 = 0.01331$

Standard Error = 0.01815

F-statistic (slopes=0) = 2.6034 (p-value=0.1083)

F-test (α=0 and β=1) = 68.63369 (p-value= lower than 0.0001)

=> rejects H_0 at the 5% level ($F_{2,193,.05}$=3.05)

Observations = 195

	Coefficients	Standard Error	t Stat	P-value
Intercept (α)	0.000658	0.001308	0.503047	0.615505
$(i_d - i_f)_t$ (β)	**-0.16014**	**0.099247**	-1.61351	0.108268

Let's test H_0, using t-tets ($t_{104,.05} = 1.96$) :

$t_{\alpha=0}$ (t-test for $\alpha = 0$): $(0.00065 - 0)/0.001308 =$ **0.503**

$\Rightarrow$ cannot reject at the 5% level.

$t_{\beta=1}$ (t-test for $\beta = 1$): (**-0.16014** – 1)/**0.0992** = **-11.695**

$\Rightarrow$ reject at the 5% level.

Formally, IFE is rejected in the short-run (both the joint test and the t-tests reject H_0). Also, note that β is negative, not positive as IFE expects. ¶

• IFE is rejected. Q: Is a "carry trade" strategy profitable?

During the 1999-2015 period, the average monthly ($i_{USD} - i_{EUR}$) was 0.001454/12=.000121. $\Rightarrow e_{f,t}^{IFE} = 0.0121\%$ per month

Actual average monthly change in the USD/EUR was .000425/12=.000035 ($e_{f,t}$ =0.0035% per month) < $e_{f,t}^{IFE}$. $\Rightarrow$ Carry trades should work!

If we use the regression to derive an expectation, then:

$E[e_{f,t}]$ = .000658-.16014*.0001454 = 0.0006347. (or a 0.06% appreciation of the EUR against the USD per month), which is different from $e_{f,t}^{IFE}$, but a bit closer to the actual $e_{f,t}$.

Recall that consistent deviations from IFE point out that carry trades are profitable: During the 1999-2015 period, USD-EUR carry trades should have been profitable. ¶

• IFE: Evidence

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

Q: Does carry trade work?

A: Burnside (2008): The average excess return of an equally weighted carry trade strategy, executed monthly, over the period 1976–2007, was about **5% per year.** (Sharpe ratio twice as big as the S&P500!, since annualized volatility of carry trade returns is much less than that for stocks).

Some long-run support:

⇒ Currencies with high interest rate differential tend to depreciate.

(For example, the Mexican peso finally depreciated in Dec. 1994.)

Expectations Hypothesis (EH)

• According to the Expectations hypothesis (EH) of exchange rates:

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

That is, on *average*, the future spot rate is equal to the forward rate.

Since expectations are involved, many times the equality will not hold. It will only hold on average.

Example: Suppose that over time, investors violate EH.

Data: $F_{t,180}$ = 5.17 ZAR/USD.

An investor expects: $E[S_{t+180}]$=5.34 ZAR/USD. (A potential profit!)

Strategy for the non-EH investor:

1. Buy USD forward at ZAR 5.17
2. In 180 days, sell the USD for ZAR 5.34.

Now, suppose everybody expects S_{t+180} = 5.34 ZAR/USD

$\Rightarrow$ Disequilibrium: everybody buys USD forward (nobody sells USD forward). And in 180 days, everybody will be selling USD. Prices should adjust until EH holds.

Since an expectation is involved, sometimes you'll have a loss, but, on average, you'll make a profit. ¶

Expectations Hypothesis: Implications

EH: $E_t[S_{t+T}] = F_{t,T}$ $\rightarrow$ On average, $F_{t,T}$ is an unbiased predictor of S_{t+T}.

Example: Today, it is 2014:II. A firm wants to forecast the quarterly S_t USD/GBP. You are given the interest rate differential (in %) and S_t.

Using IRP you calculate $F_{t,90}$: $F_{t,90} = S_t\,[1 + (i_{US} - i_{UK})_t \times T/360]$.

Data available:

$S_{t=2014:II}$ = 1.6883 USD/GBP

$(i_{US}\text{-}i_{UK})_{t=2014:II}$ = -0.304%.

Then,

$F_{t,90}$ = 1.6883 USD/GBP x [1 - 0.00304 x 90/360] = **1.68702 USD/GBP**

$\Rightarrow$ $\mathbf{S^F_{t:2014:III}}$ **= 1.68702 USD/GBP**

According to EH, if a firm forecasts S_{t+T} using the forward rate, over time, will be right on average.

=> average forecast error $E_t[S_{t+T} - F_{t,T}] = 0$.

Expectations Hypothesis: Implications

Doing this forecasting exercise each period generates the following quarterly forecasts and forecasting errors, ε_t:

Quarter	$(i_{US}-i_{UK})$	S_t	$S^F_{t+90} = F_{t,90}$	$\varepsilon_t = S_t - S^F_t$
2014:II	-0.304	1.6883		
2014:III	-0.395	1.6889	**1.68702**	0.0019
2014:IV	-0.350	1.5999	**1.68723**	-0.0873
2015:I	-0.312	1.5026	**1.59850**	-0.0959
2015:II	-0.415	1.5328	**1.50143**	0.0314
2015:III	-0.495	1.5634	**1.53121**	0.0322
2015:IV		1.5445	**1.56146**	-0.0170

Calculation of the forecasting error for 2014:III:

$$\varepsilon_{t=2014:III} = \mathbf{1.6889 - 1.68702 =} \; 0.0019.$$ ¶

Note: since $(S_{t+T} - F_{t,T})$ is unpredictable, expected cash flows associated with hedging or not hedging currency risk are the same.

Expectations Hypothesis: Evidence

Under EH, $E_t[S_{t+T}] = F_{t,T} \rightarrow E_t[S_{t+T} - F_{t,T}] = 0$

Empirical tests of the EH are based on a regression:

$$(S_{t+T} - F_{t,T})/S_t = \alpha + \beta\, Z_t + \varepsilon_t, \text{(where } E[\varepsilon_t]=0)$$

where Z_t represents any economic variable that might have power to explain S_t, for example, (i_d-i_f).

The EH null hypothesis: H_0: $\alpha=0$ and $\beta=0$. (Recall $(S_{t+T} - F_t)$ should be unpredictable!)

Usual result: $\beta < 0$ (and significant) when $Z_t = (i_d-i_f)$.
But, the R^2 is very low.

Expectations Hypothesis: IFE (UIRP) Revisited

EH: $E_t[S_{t+T}] = F_{t,T}$ $\rightarrow E_t[S_{t+T} - F_{t,T}] = 0$

Replace $F_{t,T}$ by IRP, say, linearized version:

$E_t[S_{t+T}] \approx S_t\,[1+(i_d - i_f) \times T/360]$.

A little bit of algebra gives:

$(E[S_{t+T}] - S_t)/S_t \approx (i_d - - i_f) \times T/360$ <= IFE linearized!

- EH can also be tested based on the Uncovered IRP (IFE) formulation:

$$(S_{t+T} - S_t)/S_t = e_{f,t+T} = \alpha + \beta\,(i_d - i_f) + \varepsilon_{t+T}.$$

The null hypothesis is H_0: $\alpha=0$ and $\beta=1$.

Usual Result: $\beta < 0$ $\Rightarrow$ when $(i_d - i_f)$=2%, the exchange rate appreciates by (β x .02), instead of depreciating by 2% as predicted by UIPT!

Summary: Forward rates have little power for forecasting spot rates

$\Rightarrow$ Puzzle (the forward bias puzzle)!

Explanations of forward bias puzzle:

- Risk premium? (holding a risky asset requires compensation)
- Errors in calculating $E_t[S_{t+T}]$? (It takes time to learn the game)
- Peso problem? (small sample problem)

- Risk Premium

The risk premium of a given security is defined as the return on this security, over and above the risk-free return.

- Q: Is a risk premium justified in the FX market?

  A: Only if exchange rate risk is not diversifiable.

  After some simple algebra, we find that the expected excess return on the FX market is given by:

  $(E_t[S_{t+T}] - F_{t,T})/S_t = P_{t,t+T}$.

  A risk premium, P, in FX markets implies

  $E_t[S_{t+T}] = F_{t,T} + S_t\, P_{t,t+T}$.

  If $P_{t,t+T}$ is consistently different from zero, markets will display a forward bias.

- **Example**: Understanding the meaning of the FX Risk Premium.

Data: $S_t = 1.58$ USD/GBP

$E_t[S_{t+6\text{-mo}}] = 1.60$ USD/GBP

$F_{t,6\text{-mo}} = 1.62$ USD/GBP.

- Expected change in $S_t \Rightarrow (E_t[S_{t+6\text{-mo}}]-S_t)/S_t = (1.60 - 1.58)/1.58 = 0.0127$.
- 6-mo FX premium $\rightarrow (F_{t,6\text{-mo}} - S_t)/S_t = (1.62 - 1.58)/1.58 = 0.0253$.

- In the next 6-month period:

  The GBP is expected to appreciate against the USD by 1.27%

  The forward premium suggests a GBP appreciation of 2.53%.

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    The GBP is expected to appreciate against the USD by 1.27%

    The forward premium suggests a GBP appreciation of 2.53%.

- Discrepancy: The presence of a FX risk premium, $P_{t,t+6\text{-mo}}$, which makes the forward rate a biased predictor of $S_{t+6\text{-mo}}$.

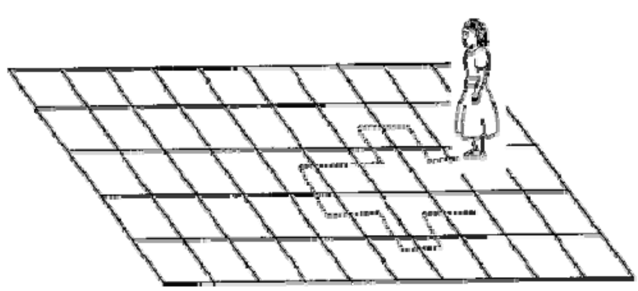
- The expected (USD) return from holding a GBP deposit will be more than the USD return from holding a USD deposit.

- Rational Investor: The higher return from holding a GBP deposit is necessary to induce investors to hold the riskier GBP denominated investments. ¶

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

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

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

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

Note: If $S_t \sim$ RW, a firm should not spend any resources to forecast S_{t+T}.

• Martingale-Random Walk Model: Evidence

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

The metric used in the comparison: forecasting error (squared).

$\Rightarrow$ The RWM performed as well as any other model.

Cheung, Chinn and Pascual (2005) checked the Meese and Rogoff's results with 20 more years of data.

$\Rightarrow$ In the short-run, RWM still the best model.

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 $E_t[S_{t+90}] = \mathbf{S^F_{t+90}}$.

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	
			$S^F_{t+90} = F_{t,90}$	$\varepsilon_{t\text{-}FR} = S_t - S^F_t$	$S^F_{t+90}=S_t$	$\varepsilon_{t\text{-}RW} = S_t - S^F_t$
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 economic fundamentals have problems explaining the short-run behavior of S_t. This is not good news if the aim of the model is to forecast S_t.

As a result of this failure, a lot of empirical models, modifying the traditional fundamental-driven models, have been 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 (or get closer to) the forecasting performance of the RWM.

A short list of the new models includes CHEERs, ITMEERs, BEERs, PEERs, FEERs, APEERs, PEERs, and NATREX. Below, I include a Table, taken from Driver and Westaway (2003, Bank of England), describing the main models used to explain EERs.

	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