International Finance

Christophe Boucher

christophe.boucher@u-paris10.fr

Session 3

Exchange rate determinants and forecasting

Roadmap

1. Long-run relationships

2. The present-value model

3. Forecasting X rates

Introduction

- As characterized by MacDonald (1999), research on the various puzzles in the empirical exchange rate literature can be broadly divided into three main areas:
  - Understand the long-run relationship between nominal exchange rates and various fundamentals (normative FEER / positive BEER)
  - The second area concerns whether fundamentals-based models can produce out-of-sample forecasts that outperform a naïve random walk?
  - The third attempts to explain the high volatility and persistence observed in real exchange rate data.

Introduction

	Short-run	Medium-run	Long-run
Industrial countries	Anderson, Bollerslev, Diebold, and Vega Clarida and Waldman Fatum and Scholnick Faust, Rogers, Swanson, and Wright (news and high frequency data)	Meese Rogoff many others Chen and Rogoff (commodity currencies) Taylor, Peel, and Sarno (nonlinear models)	Mark and Sul MacDonald (Cointegration and long horizon tests)
Non-industrial Countries	← Cerra and Saxena → (Fundamentals beat RW at 1 yr and 5 yrs Strong cointegration results)		

Introduction

- Standard exchange rate models – as exposited in textbooks and developed in research papers – link movements in exchange rates to variables such as prices, interest rates and output.

- Many empirical studies have found the links between exchange rates and such variables are weak, most prominently (but not solely) because a “random walk” model is often found to predict just about as well as any economic model.

- Other criticisms include supposed difficulty in explaining:
  - exchange rate volatility
  - high persistence in real exchange rates
  - high correlation between nominal and real exchange rates

Introduction

- This has led many researchers to conclude that the current generation of exchange rate models has failed empirically.
- Given the empirical results, should we decide that exchange rates are not determined by fundamentals?
- Probably not.
- There are reasons fundamentals aren't very helpful in forecasting exchange rates, even if currency values are determined by these fundamentals.

Introduction

- We acknowledge that exchange rate models leave much to be desired but argue that these models are not as bad as some economists think.

- Important point by Mark, Engel and West (2005), exchange rates are a present value, and hence fluctuate primarily in response to movements in expectations.

Roadmap

1. **Long-run relationships**

2. The present-value model

3. Forecasting X rates

Long-run relationships

- a large research avenue has been developed to provide medium to long-run norms for the real exchange rate.

Long-run relationships

- The old purchasing power parity (PPP) theory, which predicts that the price of a given consumption basket in different countries should converge in the long run, has experienced a surprising comeback.
- Thanks to the availability of very long time series and of panel cointegration techniques, the new consensus of the literature is that PPP holds in the very long run amongst advanced economies,
- Although deviations from PPP are long to be reversed (the half-life of deviations from PPP is typically of 4 years, see Rogoff, 1996).

Long-run relationships

- Recall that if the purchasing power parity holds, the real exchange rate is always equal to one.

- Why is the real exchange not equal to one? In other words, why doesn't PPP hold?

- Explanations:
  - Presence of tarifts and non-tariff barriers
  - transportation cost
  - non-tradable goods (Balassa Samuelson effect)

Balassa Samuelson effect

- Why the barber in Japan have a higher wage than the barber in India
- The number of customer that one barber can cut is almost the same in Japan and India
- In other words, in many non-tradable goods, the productivity of one person is the same across countries
- However, the wage rate of workers in non-tradable industry in Japan is much higher than the wage rate of the non-tradable industry in India
- The logic of the Balassa Samuelson model explain this fact very well

Balassa Samuelson effect

- The logic of Balassa Samuelson Model goes as follows:
  - Higher productivity in tradable sector
  - Tradable sector can pay higher wage due to higher profitability
  - More workers are attracted to tradable sector
  - Initially, no workers work in non-tradable sector
  - Supply of non-tradable goods will becomes so small
  - In the market of non-tradable goods, the price of the non-tradable good will increase
  - Increase of the non-tradable good implies that the wage rate in the non-tradable sector increases.
  - The increase of the price of non-tradable good and the wage rate in non-tradable sector will continue until the wage rate in the non-tradable sector and the tradable sector becomes the same

Balassa Samuelson effect

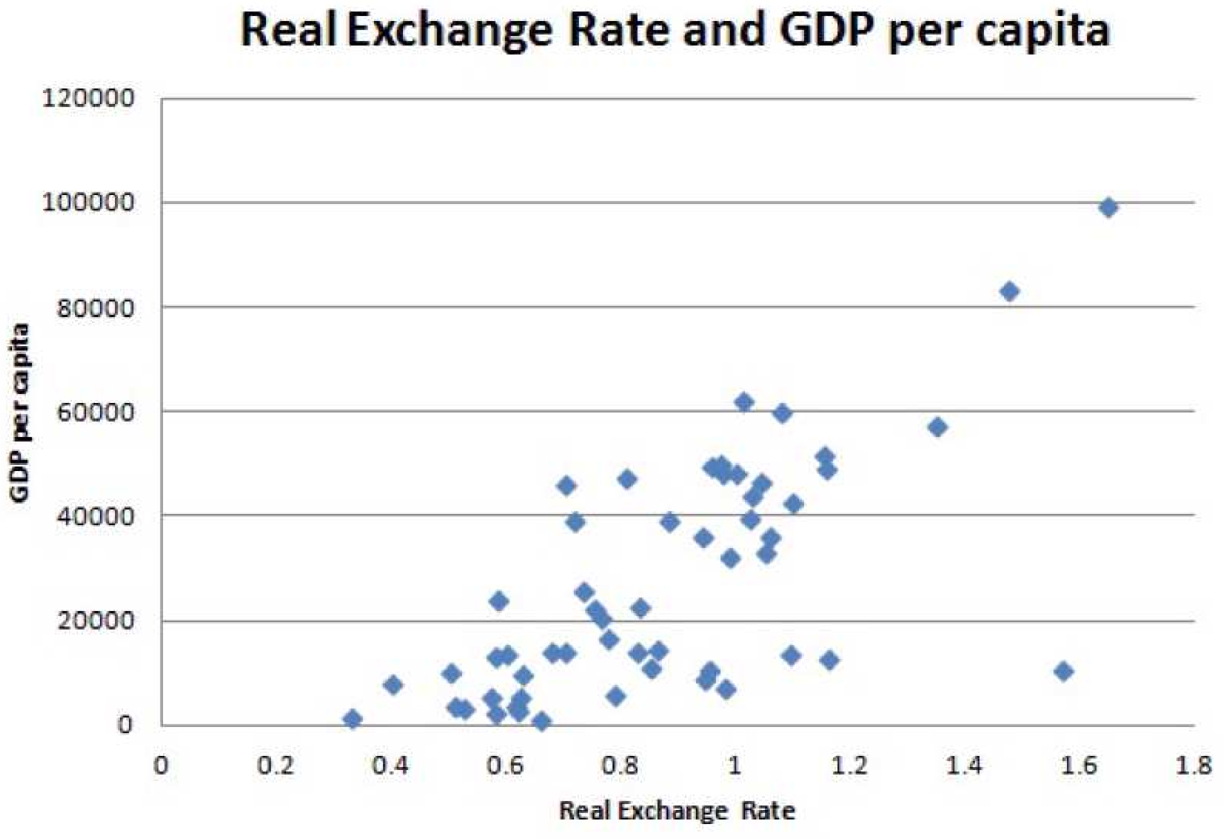
- The above mechanism explains why the wage rate of a barber in Japan is higher than the wage rate of a barber in India.

- The mechanism has three components
  - First, people want to and need to consume some non-tradable goods
  - Second, labor are mobile between tradable and non-tradable sectors
  - Third, the productivity of the tradable sector is higher in Japan than in India.

- Higher productivity of tradable industry will put upward wage pressure on workers in non-tradable industry

Balassa Samuelson effect

- The model predicts that the the price of non-tradable goods be higher in countries with higher GDP per capita



Long-run relationships

- Literature developed to provide medium to long run norms for the real exchange rate.
- The bottom line of these approaches is that, despite full capital mobility, current-account imbalances cannot grow forever, so some kind of exchange-rate adjustment will be needed at some point, although it is difficult to provide a timetable.

Long-run relationships

- Main approaches routinely used by the International Monetary Fund (IMF, 2006) for exchange-rate assessment :
  - The Fundamental Equilibrium Exchange Rate (FEER) pioneered by Williamson (1984),
  - The Behavioral Equilibrium Exchange Rate (BEER) proposed by MacDonald (1997)
  - The Natural Equilibrium Exchange Rate (NATREX) introduced by Stein (1994)

Long-run XR: a general theoretical model

One very general way of classifying equilibrium exchange-rate models is to consider the real exchange rate q_t at time t as a function of (i) a vector of economic "fundamentals" Z_t, (ii) a vector of transitory factors T_t and (iii) a random disturbance ϵ_t (see MacDonald, 2000; Driver and Westaway, 2004):

$$q_t = \beta' Z_t + \theta' T_t + \epsilon_t \tag{1}$$

where β, θ are vectors of coefficients. Three equilibrium concepts can then be disentangled:

- Short-run equilibrium:
$$q_t^{SR} = \beta' Z_t + \theta' T_t \tag{2}$$
- Medium-run equilibrium
$$q_t^{MR} = \beta' Z_t \tag{3}$$
- Long-run equilibrium
$$q_t^{LR} = \beta' \bar{Z}_t \tag{4}$$

where $\bar{Z}_t$ is the long-run equilibrium value of Z_t.

Long-run XR: a general theoretical model

- The crucial point then is to disentangle fundamentals, transitory factors and random disturbances.

Long-run XR: a general theoretical model

$$tb_t + ki_t + tr_t = ko_t \tag{5}$$

where tb_t denotes the trade balance, ki_t net capital income, tr_t current transfers[2] and ko_t the amount of net capital outflows, all expressed in percentage of GDP (i.e. dollar values divided by nominal dollar GDP). The trade balance can be expressed as a function of both domestic and foreign output gaps (y_t and y_t^*), the (log of the) relative price of foreign tradables in terms of domestic ones, e_t, and the logarithm of terms-of-trade, tot_t:

$$tb_t = \alpha_1 e_t - \alpha_2 y_t + \alpha_3 y_t^* + \alpha_4 tot_t \tag{6}$$

where α_1, α_2, α_3, $\alpha_4 > 0$. In turn, net interest receipts can be expressed as the product of the world nominal interest rate i_t^* and the net foreign asset position at the end of the last period, nfa_{t-1} (in percentage of GDP), corrected for the growth rate of nominal GDP, γ_t:[3]

$$ki_t = i_t^* \frac{nfa_{t-1}}{1+\gamma_t} \tag{7}$$

Long-run XR: a general theoretical model

Finally, net capital outflows depend on the difference between the value, in t, of the net foreign asset position inherited from the previous period, nfa_{t-1}, and the desired level of net holdings in t. Again, we follow Lane and Milesi-Ferretti (2002) and denote kg_t^* the rate of capital gains or losses on the net foreign asset position, assuming the rate of capital gains is the same on gross assets and liabilities and are expressed here in US dollars. The value of the NFA position inherited from the previous period is:

$$nfa_{t-1|t} = (1 + kg_t^*)\,\frac{nfa_{t-1}}{1+\gamma_t} \tag{8}$$

$nfa_{t-1|t}$ must be compared with desired net holdings that depend on the expected interest-rate differential. This yields:

Long-run XR: a general theoretical model

$$ko_t = k\left(\overline{nfa} + \mu\Delta r_t^e - \frac{1+kg_t^*}{1+\gamma_t}nfa_{t-1}\right) \quad (9)$$

where $\overline{nfa}$ represents the desired net foreign asset position in the absence of expected return differential, $\mu > 0$ is the sensitivity of desired net foreign assets to the expected return differential, $k > 0$ represents the adjustment speed of asset holdings, and Δr_t^e is the expected return differential:

Long-run XR: a general theoretical model

$$\Delta r_t^e = r_t^* + \Delta q_t^e - r_t \quad (10)$$

where r_t, r_t^* represent the real return rates at home and abroad, respectively, and $\Delta q_t^e = q_t^e - q_t$ denotes the expected real exchange-rate variation.[4] The relative price of foreign tradables in terms of domestic ones derives from these three equations:

$$e_t = \frac{1}{\alpha_1}\left(k(\mu \Delta r_t^e + \overline{nfa} - nfa_{t-1|t}) - \frac{i_t^*}{1+\gamma_t} nfa_{t-1} - tr_t + \alpha_2 y_t - \alpha_3 y_t^* - \alpha_4 tot_t\right) \quad (11)$$

The net foreign asset position at the end of period t, nfa_t is a pre-determined variable that evolves over time based on the following stock-flow relationship (see Lane and Milesi-Ferretti, 2002):

$$nfa_t = (1 + i_t^* + kg_t^*)\frac{nfa_{t-1}}{1+\gamma_t} + tb_t + tr_t \quad (12)$$

Long-run XR: a general theoretical model

Rearranging Equation (12), we get:

$$\Delta nfa_t = \frac{i_t^* + kg_t^* - \gamma_t}{1 + \gamma_t} nfa_{t-1} + tb_t + tr_t \qquad (13)$$

where $\Delta nfa_t = nfa_t - nfa_{t-1}$.

Long-run XR: a general theoretical model

Then, it is necessary to account for non-tradables. Denoting e_t^{NT} the (log of the) ratio of relative price of domestic non-tradables in terms of domestic tradables at home and abroad[5], it can be shown that, conditional on inter-industry labor mobility within each country:[6]

$$e_t^{NT} = z_t \tag{14}$$

where z_t represents the (log of the) relative productivity of the tradable-goods and the non-tradable goods sector, relative to the rest of the world:

$$z_t = (\pi^T - \pi^{NT}) - (\pi^{T*} - \pi^{NT*}) \tag{15}$$

π^T, π^{NT} denote the (log of) productivity in the tradable and in the non-tradable sectors, respectively. Equations (14) and (15) together state that productivity catch-up

Long-run XR: a general theoretical model

- Equations (14) and (15) together state that productivity catch-upin traded goods should be accompanied by a rise in the relative price of non-tradables because the latter sector suffers from a rise in domestic wages without a rise in productivity similar to that in the traded-goods sector (Balassa-Samuelson effect).

Long-run XR: a general theoretical model

tivity similar to that in the traded-goods sector (Balassa-Samuelson effect).[7] If η denotes the share of tradables in the economy, the logarithm of the real exchange rate can be written as:

$$q_t = e_t - (1-\eta)e_t^{NT} \tag{16}$$

Plugging (11) and (14) into (16), we get:

$$q_t = f\left(\overset{+}{\Delta r_t^e}, \ \overset{-}{tot_t}, \ \overset{+}{(\overline{nfa} - nfa_{t-1|t})}, \ \overset{-}{nfa_{t-1}}, \ \overset{-}{tr_t}, \ \overset{+}{y_t}, \ \overset{-}{y_t^*}, \ \overset{-}{z_t} \right) \tag{17}$$

where the signs of the partial derivatives are indicated on the top of each explanatory variable.[8] This general formulation states that the domestic currency should depreciate

Long-run XR: a general theoretical model

- This general formulation states that the domestic currency should depreciate in real terms (q_t should rise) following:
  - a rise in the expected return differential on assets denominated in foreign currencies,
  - a fall in terms of trade,
  - a decline in the net foreign asset position compared to the desired one,
  - a rise in the domestic output gap,
  - a fall in the foreign output gap or
  - a fall in relative productivity in tradables compared to the rest of the world.

Long-run XR: a general theoretical model

- In the *very long run*, prices and stocks have adjusted to equilibrium and productivity levels are equalized. In Equation (17), this translates into $y_t = y_t^* = 0$, $z_t = 0$, $\Delta r_t^e = 0$ and $nfa_t = nfa_{t-1} = \overline{nfa}$. Note that the latter condition does not rule out net capital outflows: with $\Delta r_t^e = 0$ and $nfa_{t-1} = \overline{nfa}$, Equation (9) yields:

$$ko_t = k\left(1 - \frac{1 + kg_t^*}{1 + \gamma_t}\right)\overline{nfa} \qquad (18)$$

For example, a country with a positive equilibrium NFA position will experiment permanent capital outflows if GDP growth exceeds capital gains. In the very long run, however, due to perfect arbitrage across markets, α_1 can be thought as infinite in Equation (6). Hence, net capital outflows and the NFA position have no impact on the real exchange rate in the very long run (see Equation 11): q_t is a constant value, which amounts to purchasing power parity:

$$q_t = constant \qquad (19)$$

Long-run XR: a general theoretical model

- In the *long run*, only prices and stocks have adjusted. The expected return differential is zero (or equal to a constant risk premium), but productivity catch-up is still under way ($z_t \neq 0$), whereas the net foreign asset position is at its equilibrium level: $nfa_t = nfa_{t-1} = \overline{nfa}$.[9] Plugging Equation (6) into (13) with $y_t = y_t^* = 0$ and $\Delta nfa_t = 0$, we get:

$$e_t = -\frac{1}{\alpha_1}\left(\frac{i_t^* + kg_t^* - \gamma_t}{1+\gamma_t}\overline{nfa} + tr_t + \alpha_4 tot_t\right) \tag{20}$$

Equation (20), which is embodied in (17), points to a depreciation of the real exchange rate when the NFA position falls, because the trade balance must be higher to compensate for lower interest receipts. Accounting for non-tradables, the real exchange rate also depends on the relative level of productivity in both sectors, with productivity catch-up implying real exchange-rate appreciation.

Long-run XR: a general theoretical model

- In the *medium run*, neither stocks nor productivities are at their equilibrium level. Only domestic prices have adjusted, which means that output gaps have been closed: $y_t = y_t^* = 0$. Net capital outflows can be positive or negative (see Equation 9). Consistently, the current account must be positive in the former case, negative in the latter one, which has implications for the relative price of tradables. Indeed, plugging (9), (7) and (6) into (5), and holding $y_t = y_t^* = 0$, we get:

$$e_t = \frac{1}{\alpha_1}\left[k\left(\overline{nfa} + \mu\Delta r_t^e - \frac{1+kg_t^*}{1+\gamma_t} nfa_{t-1}\right) - \frac{i_t^*}{1+\gamma_t} nfa_{t-1} - tr_t - \alpha_4 tot_t\right] \tag{21}$$

which, again, can be combined with the Balassa-Samuelson effect. For instance, large net capital inflows can justify an appreciated exchange rate in the medium run, even if the NFA position is already negative. This is not the case in the long run where a negative NFA position normally leads to a depreciated currency.

Long-run XR: a general theoretical model

- In the *short run*, finally, prices have not adjusted, which means that output gaps have not been closed and that the real exchange rate is not stabilized. Hence, the equilibrium exchange rate is the solution of Equation (17) with all variables at their observed, short-run values. This rate can be viewed as the short-run fundamental market rate.

Long-run XR: PPP

- The very long-term: PPP

Table 1: PPP exchange rate: USD per euro in 2007

Country	WDI consumer (1)	OECD consumer (2)	Big Mac (3)	BLS manuf. (4)	Eurostat manuf. (5)	Eurostat all (6)
France	1.16	1.12	-	0.99	0.94	0.81
Germany	1.13	1.14	-	0.78	0.92	0.89
Italy	1.23	1.17	-	1.15	1.24	1.01
Spain	1.28	1.30	-	1.35	1.54	1.40
Euro area	–	–	1.10	–	1.09	1.04

Sources: World Development Indicators 2007; OECD Economic Outlook 81, 2007; The Economist, February 2007; US Bureau of Labor Statistics, April 2007.

Long-run XR: FEERS/BEERS

- The medium to long run: FEERs and BEERs

- The first concept is the Fundamental Equilibrium Exchange Rate (FEER). It is derived from Equation (5) with net capital outflows k_{ot} exogenously set at a "target" level that corresponds to “sustainable" net capital outflows ("external balance") and output gaps set at zero ("internal balance").

Long-run XR: FEERs

- There are two ways of calculating FEERs.
  - The first one consists in
    - estimating the coefficients of the trade-balance equation (6).
    - Then, an "adjusted" current-account balance can be calculated by setting output gaps to zero (internal balance).
    - Finally, the FEER is calculated by inverting the current-account equation and deriving the real exchange rate that would bring the adjusted current account to its target level.
  - The second methodology on macro-econometric models.
    - As in the first one, current-account targets are defined and the output gap is set to zero.
    - But here, the FEER is derived from simulating the whole model.

- This second approach is used for instance by the National Institute for Economic and Social Research in London, based on its macro model NIGEM (Barrell et al. 2007).

Long-run XR: BEERs

- The second research avenue (BEER models), pioneered by Faruqee (1995), MacDonald (1995) relies on the direct estimation of Equation (17).

- The BEER is derived as the prediction of the estimated equation,

- Exchange-rate misalignments are calculated by comparing the BEER with the observed exchange rate.

- One can either derive a long-run BEER or a medium-term one by setting explanatory variables at their equilibrium or observed values (Equations (11) and (20), respectively).

Long-run XR: FEERS/BEERS

- Because it relies on a cointegration relationship, the BEER approach generally provides equilibrium exchange rates that are closer to observed rates than in the FEER approach.

Long-run XR: EUR/USD estimates

Table 5: Real effective misalignments in 2005 with the FEER approach (in %)

Country	Benchmark targets[b]	Medium-run targets[c]			Long-run targets[d]
		T=5	T=7	T=10	
United States	-48.5	-142.9	-131.3	-122.5	-91.8
Canada	−4.1	9.1	7.1	5.5	7.5
Japan	33.4	108.0	95.4	86.0	54.1
Euro area	−9.3	-21.8	-18.7	-16.3	−10.9
United Kingdom	6.0	-25.2	-20.6	-17.2	-9.5
Mexico	−43.9	-27.6	-22.3	-18.3	27.0
Korea	−5.4	16.7	9.8	4.6	5.7
Australia	−40.1	-76.9	-67.3	-60.1	-31.7
Argentina	89.7	38.5	38.0	37.6	138.8
Brazil	30.6	-18.5	-9.9	-3.5	128.1
China	73.9	161.7	144.7	132.1	120.5
Indonesia	30.4	63.3	55.0	48.8	44.0
India	−36.2	152.4	115.4	87.7	280.0
Turkey	−52.9	-70.5	-61.9	-55.5	18.7
South Africa	−22.4	-19.9	-24.5	-27.8	-28.0

Long-run XR: EUR/USD estimates

Table 8: Real effective misalignments in 2005 with the BEER approach (in %)

	Medium-run		Long-run	
Country	prod1	prod2	prod1	prod2
United States	-6.7	-2.7	-2.2	3.2
Canada	8.3	11.4	5.8	8.1
Japan	7.9	-6.1	2.1	-13.8
Euro area	-6.7	-9.5	-4.7	-6.9
United Kingdom	-15.9	-15.9	-12.1	-10.8
Mexico	-15.8	-17.3	-14.2	-15.2
Korea	-12.4	-22.1	-15.9	-26.8
Australia	-4.3	-2.2	1.4	5.3
Argentina	63.5	40.0	63.3	39.7
Brazil	-29.2	-15.8	-27.1	-12.9
China	31.0	40.2	22.3	28.7
Indonesia	13.1	43.1	10.1	-39.1
India	9.7	-14.5	5.9	-19.5
Turkey	-1.6	-24.3	0.5	-21.5
South Africa	3.6	21.7	2.0	19.7

Note: a positive value points to an undervalued currency. Source: authors' calculations.

Long-run XR: various models

Table 1: Summary of empirical approaches to estimating equilibrium exchange rates

	UIP	PPP	Balassa-Samuelson	Monetary Models	CHEERs	ITMEERs	BEERs	FEERs	DEERs	APEERs	PEERs	NATREX	SVARs	DSGE
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	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
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 non-traded 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	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
Relevant Time Horizon	Short run	Long run	Long run	Short run	Short run (forecast)	Short run (forecast)	Short run (also forecast)	Medium run	Medium run	Medium / Long run	Medium / Long run	Long run	Short (and long) run	Short and long run
Statistical Assumptions	Stationarity (of change)	Stationary	Non-stationary	Non-stationary	Stationary, with emphasis on speed of convergence	None	Non-stationary	Non-stationary	Non-stationary	Non-stationary (extract permanent component)	Non-stationary (extract permanent component)	Non-stationary	As with theoretical	As with theoretical
Dependent Variable	Expected change in the real or nominal	Real or nominal	Real	Nominal	Nominal	Future change in the Nominal	Real	Real Effective	Real Effective	Real	Real	Real	Change in the Real	Change relative to long-run steady state
Estimation Method	Direct	Test for stationarity	Direct	Direct	Direct	Direct	Direct	Underlying Balance	Underlying Balance	Direct	Direct	Direct	Direct	Simulation

Source: Driver, R.L. and P.F. Westaway (2004), “Concepts of equilibrium exchange rates”, Bank of England working paper No. 248.

Roadmap

1. **Long-run relationships**

2. **The present-value model**

3. Forecasting X rates

The present-value model

- Engel and West (2005) argue that the exchange rate disconnect is consistent with exchange rates being determined by fundamental variables.

- They show that existing exchange rate models can be written in a present value asset pricing format.

- In these models, exchange rates are determined not only by current fundamentals but also by expectations of what the fundamentals will be in the future.

The present-value model

- Under the Engel/West explanation, judging exchange rate models by their ability to forecast is too harsh a standard:
  - If exchange rates are determined by fundamentals in the same way as other asset prices,
  - current fundamentals can't forecast exchange rates better than a random walk,
  - even if the asset pricing model correctly captures the relation between economic fundamentals and exchange rates.

- In this case, fundamental based models are still appropriate for economic analysis, such as exchange rate and trade policy analysis – they are just useless in forecasting.

The present-value model

- If the exchange rate is determined by expected future fundamentals, today's currency values should contain information about tomorrow's fundamentals.
- Engel and West (2005) provide evidence that exchange rates do indeed Granger-cause fundamentals.
- Engel and West (2006) find that deviations of real exchange rates from steady state values forecast inflation and output gaps.
- Chen, Rogo, and Rossi (2010) find that “commodity currencies“ robustly forecast commodity prices (exchange rates in Australia, Canada, Chile, New Zealand, and South Africa).

The present-value model

- Sarno and Schmeiling (2013) test the validity of this key empirical prediction of present-value models in a sample of 35 currency pairs ranging from 1900 to 2009.

- Employing a variety of tests, they find that exchange rates have strong and signicant predictive power for nominal fundamentals (ination, money balances, nominal GDP),

- whereas predictability of real fundamentals and risk premia is much weaker and largely conned to the post-Bretton Woods era.

- Overall, they uncover ample evidence that future macro fundamentals drive current exchange rates.

The present-value model

- Three important new facts:
  - Under some plausible parameterizations, popular exchange rate models imply that nominal exchange rates are nearly a random walk
  - Recent work on “Taylor rule” models has developed a model that links exchange rate behavior to monetary policy rules for setting interest rates. Ongoing quantitative work (both regression based and calibrated) suggests that the models capture some salient features of exchange rates
  - New or updated empirical results find links between exchange rates and fundamentals consistent with the asset pricing view

The present-value model

The asset price approach to exchange rates relies on the fact that the exchange rate, as any other asset price, can be written as the discounted present value of future fundamentals:

$$s_t = (1-b)\sum_{i=0}^{\infty} b^i \mathbb{E}_t[f_{t+i}] \qquad (1)$$

where s is the log nominal exchange rate, b is a parameter that depends on the structure of an underlying macro model, and f denotes the set of macro fundamentals. The above present-

The present-value model

underlying macro model, and f denotes the set of macro fundamentals. The above present-value formulation starts from the general idea that spot rates are driven by fundamentals and expected spot rates, i.e.

$$s_t = (1-b)f_t + b\mathbb{E}_t[s_{t+1}] \tag{2}$$

and Eq. (1) then follows from iterating forward Eq. (2) provided that the no-bubbles condition $b^i\mathbb{E}_t[s_{t+i}] = 0$ holds for $i \to \infty$ and that current fundamentals are observable. Thus, Eq. (1) suggests that current exchange rates should be informative for future fundamentals.

The present-value model

- The general formulation in Eq. (1) takes no stand on which fundamentals to include in exchange rate determination so that the menu of fundamentals will be driven by choosing a particular exchange rate model.

The present-value model

- The “fit” of a random walk model:
- Classic reference is Meese and Rogoff (1983)
- Random walk model is not perfect, but in terms of forecasting ability, is difficult to beat (the benchmark when forecasting)
- One interpretation: “...the major weakness of international macroeconomics” (Bacchetta and van Wincoop, 2006)

The present-value model

- A second interpretation: in an efficient market, the exchange rate will follow a random walk

- Problem: the classic “efficient market,” model of asset prices does not predict a random walk

- Instead, it states that there are no predictable profit opportunities for a risk-neutral investor to exploit

- The implication for exchange rates: uncovered interest parity (UIP) should hold, and interest rate differentials should predict exchange rate changes.

The present-value model

- Engel and West (2005) claim:

Under some plausible parameterizations, popular exchange rate models imply that nominal exchange rates are nearly a random walk

The present-value model

- Illustrate with calibration of stochastic, discrete-time version of Dornbusch (1976)

- Model essentials:
  - simple monetary model, with fundamentals = linear combination of relative money and relative outputs
  - fundamentals following a random walk
  - uncovered interest parity (i.e., no risk premium)
  - only two parameters: interest semi-elasticity of money demand, and speed of price adjustment.

- Familiar result: Because there is price stickiness, movements in exchange rates are predictable. For example, a positive shock to home money supply leads to a jump (depreciation) in the exchange rate–a jump so big that the exchange rate “overshoots.” The exchange rate then predictably declines.

The present-value model

- But: a plausible calibration of the two parameters
  - half-life of price adjustment is 2.4 quarters,
  - interest rate semielasticity consistent with estimates of quarterly money demand

- implies ....

- that the $R2$ of a regression of the change in the exchange rate on past data is about .01.

The present-value model

- General analytical and simulation results in Engel and West (2005):
  - basic conditions:
    - (1) linear present value model,
    - (2) fundamental that is I(1) or nearly so
    - (3) discount factor near 1

- Impliy near random walk
  - “fundamental” = linear combination of home and foreign money supplies, outputs, price levels, productivity levels, interest rates ....
  - allows various versions of monetary model (sticky price, flexible price, ...) and of Taylor rule model
  - allows complex dynamics in the fundamentals, private agents forecasting from a multivariate information set and/or forecasting with data that are not available to the econometrician....

The present-value model

- caveat:

formally, requires that risk premium be absent (informally, that the risk premium not be particularly volatile)

The present-value model

- Under these conditions, we should not be surprised to find that exchange rate changes seem to be disconnected from previous movements in fundamentals such as relative money supplies, relative outputs or relative inflation rates

- This result is quantitative, and is consistent with the qualitative implication that there are predictable movements in exchange rates

The present-value model

- Empirical evidence

- Various bits of evidence indicate that a present value model captures important features of exchange rate behavior

The present-value model

- Taylor rule models: “Taylor rule” studies tie exchange rates to interest rate rules
- Clarida and Waldman (2007) and related papers
- Use of survey data in Taylor rule model leads to reasonable coefficients in equation relating real exchange rates to fundamentals
- Engel and West (2006) and Mark (2007): such models track the broad movements in DM/U.S. $ real exchange rate, rationalizing high persistence in real exchange rates and high correlation between nominal and real exchange rates

The present-value model

- Out of sample tests of predictability, using bivariate and panel data, structured in such a way as to possibly capture the effects of a risk premium, find some modest predictability of exchange rate changes

The present-value model

- Conclusion

- Reasonable calibrations of some exchange rate models imply that exchange rates should follow an approximate random walk

- Various bits of evidence indicate that exchange rates are tied to fundamentals in ways broadly consistent with present value models

Roadmap

1. Long-run relationships

2. The present-value model

3. **Forecasting X rates**

Forecasting X rates

- Predicting exchange rates is still an inexact science.
- Economic models perform poorly, and a plethora of alternative methods have been attempted.
- Objective: reviewing various predictors, models, and data specifications.
- Despite a large and divergent literature chasing this holy grail, the toughest benchmark remains the random walk without drift..

Forecasting X rates

- Since Meese and Rogoff (1983a,b, 1988), it has been well known that exchange rates are very difficult to predict using economic models.
- However, the recent literature has identified new predictors and models that claim to forecast exchange rates (Gourinchas and Rey 2007, Mark 1995, and Molodtsova and Papell 2009, among others).
- Unfortunately, the findings in the literature are sometimes contradictory.

Forecasting X rates

- Researchers trying to forecast exchange rates typically face several choices.
  - choose a predictor (economic variable).
  - choose a model (single-equation, multiple equations and panel models / linear / time varying parameters)
  - specify the data
  - Which criteria for forecast evaluation.

Forecasting X rates

- To choose a predictor.
  - There is no shortage of predictors used in the literature: interest rates, output, money supply, trade balance, net foreign asset positions, commodity prices, etc.
  - Are any of these predictors is capable of forecasting future exchange rates better than simply using the exchange rate value today, which is what the random walk would predict?

Forecasting X rates

- No shortage of models used in the literature:
  - linear,
  - nonlinear,
  - nonparametric,
  - panel,
  - factor,
  - forecast combinations,
  - Bayesian model averaging,
  - etc.

Forecasting X rates

- Forecasts based:
  - on revised or realtime data.
  - Filtered, detrended or raw data
  - Which frequency
  - Which countries should be considered? Aadvanced/emerging, hyperinflation or not, commodity countries
  - What is the forecast horizon? Hours, days, weeks, month, quarters, years?

Forecasting X rates

- Which criterion?
  - mean squared forecast error,
  - mean absolute errors,
  - Utility based
  - Direction of prediction measures?
  - In-sample/out-ofsample tests?
  - Relative or absolute forecasting performance measures?

Forecasting X rates

- Empirical literature: inconsistent results
  - Papers offer contradictory results, and rely on different predictors, tests, samples or databases.
  - It is possible that such predictors might have lost their forecasting ability, or may not be robust to other databases or samples.
  - In addition, while a predictor might be successful according to one measure of performance, it may not be so according to another.

Forecasting X rates

- Rossi (2013, JEL) provides guidance to researchers navigating the existing literature and a reliable overview of established findings that can be helpful in deciding
  - which predictor to use,
  - which model to estimate,
  - which data to collect, and
  - which forecast evaluation tests to utilize

Forecasting X rates

- "Does anything forecast exchange rates?".

- The answer is ….

- … “"It depends." It depends on the choice of predictor, forecast horizon, sample period, model, and forecast evaluation method.

Forecasting X rates

- Predictability is most apparent when one or more of the following hold:
  - The predictors are Taylor rule and net foreign assets fundamentals,
  - The model is linear, and a small number of parameters are estimated.
  - The toughest benchmark is the random walk without drift.

Forecasting X rates

- There is some instability over samples for all models,

- There is no systematic pattern across models in terms of which horizons or which sample periods the models predict best.

- Among the negative findings on which the literature has reached a consensus, typically:
  - PPP and monetary models have no success at short (less than 23 year) horizons.

Basics about Forecasting

- Basics about forecasting
  - Linear models
  - In-sample vs out-of sample
  - Oos: Rolling vs recursive
  - Traditional predictors

Basics about Forecasting

Let the (log) of the exchange rate be denoted by s_t and let the (univariate) predictor (or fundamental) be denoted by f_t. Examples of predictors used in the literature are discussed in detail in the next section, and the choice of the data is discussed in Section 5.

The relationship between the exchange rate and its fundamental can be described by several models (see Section 4). For expositional purposes, let the model be linear and such that it does not include a constant term:

$$E_t\left(s_{t+h} - s_t\right) = \beta f_t, \quad t = 1, 2, ..., T,$$

where T is the total size of the available sample and h is the forecast horizon.

Basics about Forecasting

The model's performance is typically evaluated relative to that of a benchmark model. Let the benchmark model be the random walk without drift:

$$E_t\left(s_{t+h} - s_t\right) = 0.$$

In fact, we will argue in Section 6 that the random walk without drift is the appropriate benchmark for the analysis.

Basics about Forecasting

The predictive ability of the fundamental can be evaluated according to in-sample fit or out-of-sample forecast performance. In-sample fit is typically evaluated by estimating β over the full sample,

$$\widehat{\beta}_T = \left(\sum_{t=1}^{T} f_t^2\right)^{-1} \left(\sum_{t=1}^{T} f_t \left(s_{t+h} - s_t\right)\right),$$

and calculating a t-test on β: if the fundamental contains relevant information, then β should be different from zero. The latter is known as an in-sample (traditional) Granger-causality test. If the test rejects, it signals that the predictor contains useful information for explaining exchange rate fluctuations over the full sample. However, this does not necessarily mean that the predictor contains useful information to predict exchange rate fluctuations in real-time. To assess the latter, it is common to turn to forecasting.

Basics about Forecasting

- Different from Meese and Rogoff exercise

Meese and Rogoff (1983a, 1988) focus on models where exchange rate fluctuations are explained by the simple single-equation model:

$$E_t\left(s_{t+h} - s_t\right) = \beta_0 + \beta_1' f_{t+h}, \tag{9}$$

where the future, realized values of the fundamental f_{t+h} are used. We refer to (9) as the *"single-equation, contemporaneous, realized fundamental model"*. The actual, rather than the forecasted, value of the fundamentals is used as a predictor by Meese and Rogoff (1983a,b, 1988) to make sure that the lack of predictability of exchange rates is not due to poor forecasts of the fundamentals. The parameters are estimated either by simple OLS or by GMM (to deal with the endogeneity of the predictors). Meese and Rogoff (1983b) calibrate the parameter in a grid to explore the robustness of their results to possible inconsistencies in the parameter estimates. Cheung, Chinn and Pascual (2005) forecast exchange rates

Basics about Forecasting

To evaluate the models' out-of-sample forecasting ability, the sample is split into two parts: the in-sample portion, consisting of observations from 1 to R, and the out-of-sample portion, of observations $R+h$ to $T+h$, of size $P \equiv T-R+1$. In the rolling window forecasting scheme, the parameter is re-estimated over time using the most recent R observations, where R is known as the estimation window size:

$$\widehat{\beta}_t = \left(\sum_{j=t-R+h+1}^{t} f_{j-h}^2 \right)^{-1} \left(\sum_{j=t-R+h+1}^{t} f_{j-h} \left(s_j - s_{j-h} \right) \right), \ t = R, R+1, ..., T,$$

to obtain a sequence of P h-step-ahead out-of-sample forecast errors, $\varepsilon_{t+h|t}^{f} \equiv s_{t+h} - s_t - \widehat{\beta}_t f_t$, $t = R, R+1, ..., T$. Note that the random walk forecast error is simply $\varepsilon_{t+h|t}^{rw} \equiv s_{t+h} - s_t$.

Under the rolling window forecast scheme, the model parameters are re-estimated progressively over time. An alternative forecast scheme is the recursive one, where the model parameters are always re-estimated using all the previous observations. That is, $\widehat{\beta}_t = \left(\sum_{j=h+1}^{t} f_{j-h}^2 \right)^{-1} \left(\sum_{j=h+1}^{t} f_{j-h} \left(s_j - s_{j-h} \right) \right)$, $t = R, R+1, ..., T$.

Basics about Forecasting

The forecasting ability of the model is measured by a loss function; for example, a common choice is the Root Mean Squared Forecast Error (RMSFE), which will be the objective of our analysis unless otherwise noted:[9]

$$RMSFE_f \equiv \frac{1}{P}\sum_{t=R}^{T}\left(\varepsilon_{t+h|t}^{f}\right)^2.$$

The model forecasts better than the random walk if $RMSFE_f < RMSFE_{rw} \equiv \frac{1}{P}\sum_{t=R}^{T}\left(\varepsilon_{t+h|t}^{rw}\right)^2$. To judge whether the model forecasts significantly better, one typically tests whether $RMSFE_f - RMSFE_{rw}$ is equal to zero against the alternative that the difference is negative, i.e. using a t-test. Several methods to compute the standard errors and other available test statistics

Predictors (variables)

- Traditional Predictors
  - Interest Rate Differentials (UIP of Fisher, 1896)
  - Price and Inflation Differentials (PPP of Cassel, 1918)
  - Money and Output Differentials (Monetary models of Frenkel 1976 and Mussa, 1976).
  - Productivity Differentials (rel GDP per employee) - Cheung, Chinn and Pascual (2005)
  - Portfolio Balance (cumulated trade balance differentials, cumulated current account balance differentials, and government debt) by Frankel, 1982; Hooper and Morton, 1982)

Predictors (variables)

- Model: Taylor rule fundamentals

- Engel and West (2005, 2006) and Molodtsova and Papell (2009) propose fundamentals based on a Taylor rule for monetary policy (Taylor, 1993).

$$r_{t+1} = \phi\left(\pi_t - \pi^\dagger\right) + \gamma y_t^{gap} + r^\dagger,$$

- if one considers two economies, both of which set interest rates according to a Taylor rule, by UIP their bilateral exchange rate will reflect their relative interest rates, and thus:
  - their output gaps and
  - their inflation levels.

Predictors (variables)

Molotdsova and Papell (2009) amend the Taylor rule to take into account two empirical facts. First, in an open economy setting, as the Central Bank attempts to maintain the nominal exchange rate at its purchasing power parity level (Svensson, 2000), monetary policy also depends on the real exchange rate, $q_t \equiv s_t - p_t + p_t^*$. Second, interest rate changes are sluggish since Central Banks prefer to avoid over-achieving their target (as in Clarida, Gali and Gertler, 1998). By adding these features to the original Taylor rule, they obtain:

$$i_{t+1} = (1-\rho)\left(\mu + \lambda\pi_{t+1} + \gamma y_{t+1}^{gap} + \delta q_t\right) + \rho i_t + v_{t+1}$$

for all countries, whereas for the US $\delta = 0$, and v_{t+1} is the monetary policy shock. That is, using asterisks to denote foreign country variables:

$$i_{t+1}^* = (1-\rho^*)\left(\mu^* + \lambda^*\pi_t^* + \gamma^* y_t^{gap*} + \delta^* q_t\right) + \rho^* i_t^* + v_{t+1}^*$$
$$i_{t+1} = (1-\rho)\left(\mu + \lambda\pi_t + \gamma y_t^{gap}\right) + \rho i_t + v_{t+1}.$$

Predictors (variables)

By taking the difference of the two equations, using UIRP and re-defining the coefficients, one obtains the specification in Molodtsova and Papell (2009):

$$E_t s_{t+1} - s_t = \widetilde{\mu} + \widetilde{\delta} q_t + \widetilde{\lambda}^* \pi_t^* + \widetilde{\gamma}^* y_t^{gap*} + \widetilde{\lambda} \pi_t + \widetilde{\gamma} y_t^{gap} + \rho i_t - \rho^* i_t^*, \qquad (7)$$

Predictors (variables)

- Both the in-sample and the out-of-sample empirical evidence are mostly favorable to Taylor-rule fundamentals, although with exceptions.

- Taylor rules are generally deemed to be a good description of monetary policy in the past three decades, but monetary policy may have changed during the recent 2007 financial crisis.
  - Molodtsova and Papell (2012) study exchange rate forecasting during the financial crisis by including indicators of financial stress in the Taylor rule.
  - Adrian et al. (2011) use instead measures of liquidity such as funding liquidity aggregates of US financial intermediaries measured by stocks of US dollar financial commercial paper and overnight repos.
  - Both the latter papers find positive evidence.

Predictors (variables)

- External Imbalance Measures

- Gourinchas and Rey (2007) argue that not only the current account, but the whole dynamic process of net exports, foreign asset holdings and return on the portfolio of net foreign assets are important predictors of exchange rates.

Predictors (variables)

- When a country experiences a current account imbalance, the traditional intertemporal approach to the current account suggests that the country will need to run future trade surpluses to reduce this imbalance.

- Gourinchas and Rey (2007) argue instead that part of the adjustment can take place through a wealth transfer between that country and the rest of the world occurring via a depreciation of the value of its currency.

- Thus, they propose "net foreign assets" (NXA) as a potential predictor for future exchange rate fluctuations.

Predictors (variables)

- NXA is the deviation from trend of a weighted combination of gross assets, gross liabilities, gross exports and gross imports, and measures the approximate percentage increase in exports necessary to restore external balance,

- that is, to restore the long run equilibrium of net exports and net foreign asset ratios.

Predictors (variables)

- The empirical evidence is overall favorable to external imbalance measures.

- Gourinchas and Rey (2007) and Della Corte, Sarno and Sestieri (2010) find that the net foreign asset model can predict (effective) exchange rates out-of-sample significantly better than the ran-
- dom walk at both long and short horizons.

- Alquist and Chinn (2008) find that in some sub-sample the net foreign asset model forecasts (bilateral) exchange rates better than the random walk at short horizons for some countries; the results are however less favorable at longer horizons.

Predictors (variables)

- Commodity Prices and Other Predictors
- Chen and Rogoff (2003) focus attention on commodity prices as a potential new macroeconomic fundamental for exchange rates.
- They focus on “commodity currencies”, that is exchange rates for countries where primary commodities constitute a significant share of exports (i.e. Australia, Canada and New Zealand).

Predictors (variables)

- Their main idea is that, typically, ex-change rates are endogenously determined in equilibrium together with other macroeconomic variables, so it is difficult to predict exchange rate changes based on reduced-form models.
- However, if it were possible to identify an exogenous shock to exchange rates, that would cleanly predict exchange rate fluctuations.
- Chen and Rogoff (2003) argue that commodity price changes act as “essentially exogenous shocks” for small open economies; the economies with a large share of exports in primary commodities will typically experience exchange rate appreciations when the price of their commodity exports increases.

Synhesis: Main variables in economic models

Table 1. Literature Review: Predictors and Economic Models

Predictors (f_t)	Economic Fundamentals	Mnemonics
$i_t - i_t^*$	Interest Rate Differentials	i
$F_t - s_t$	Forward Discount	F
$p_t - p_t^*$	(Log) Price Differentials	p
$\pi_t - \pi_t^*$	Inflation Differentials	π
$y_t - y_t^*$	(Log) Output Differentials	y
$m_t - m_t^*$	(Log) Money Differentials	m
z_t	Productivity Differentials	z
$b_t - b_t^*$	Asset Differentials	b
$y_t^{gap} - y_t^{gap*}$	Output Gap Differentials	y^{gap}
nxa_t	Net Foreign Assets	nxa
CP_t	Commodity Prices	CP

Synhesis: Main variables in economic models

Model	f_t	Mnemonics
UIRP (CIRP)	$i_t - i_t^*$; $(F_t - s_t)$	i, F
PPP	$p_t - p_t^*$ or $\pi_t - \pi_t^*$	p, π
Monetary Model with Flexible Prices (I)	$[(i_t - i_t^*), (y_t - y_t^*), (m_t - m_t^*)]'$	i, y, m
Monetary Model with Flexible Prices (II) (or Frenkel-Bilson Model)	$[(y_t - y_t^*), (m_t - m_t^*)]'$	y, m
Monetary Model with Sticky Prices (I)	$[(i_t - i_t^*), (y_t - y_t^*), (m_t - m_t^*), (p_t - p_t^*)]'$	i, y, m, p
Monetary Model with Sticky Prices (II) (or Dornbush-Frankel Model)	$[(i_t - i_t^*), (y_t - y_t^*), (m_t - m_t^*), (\pi_t - \pi_t^*)]'$	i, y, m, π
Model with Productivity Differentials (or Balassa-Samuelson (1964) Model)	$[(i_t - i_t^*), (y_t - y_t^*), (m_t - m_t^*), z_t]'$	i, y, m, z
Portfolio Balance Model (or Hooper and Morton (1982) Model)	$[(i_t - i_t^*), (b_t - b_t^*)]'$	i, b
Taylor Rule Model	$[(\pi_t - \pi_t^*), (y_t^{gap} - y_t^{gap*})]'$	π, y^{gap}
Net Foreign Asset Model	nxa_t	nxa
Commodity Prices	CP_t	CP

Synthesis about Predictors

- The literature has considered a wide variety of predictors.
  - Overall, the empirical evidence is not favorable to traditional economic predictors, except possibly for the monetary model at very long horizons and the UIRP at short horizons, although there is disagreement in the literature.
  - Both Taylor-rule fundamentals and net foreign asset positions have promising out-of-sample forecasting ability for exchange rates, although some papers question the robustness of the results.
  - The consensus in the literature is that these fundamentals have more out-of-sample predictive content than traditional fundamentals; the disagreement in the literature is in the degree to which these new fundamentals can explain the Meese and Rogoff puzzle.

See you next week….