EC933-G-AU – Lecture 9

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Foreign Exchange Market Efficiency and Microstructure: Models with Noise Traders

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Plan of talk

- **introduction**
1. forex market efficiency
   1. testing CIP
   2. testing UIP
2. official forex market intervention
3. forex market microstructure: Jeanne-Rose (2002) model with noise traders
   1. under *exogenous* number of noise traders
   2. under *endogenous* entry of noise traders
- **wrap-up**

Aim and learning outcomes

- **aim**: introduce and illustrate the literature on forex market efficiency and on modelling departures from rationality
- **learning outcomes**
  - summarise and critically assess
    - the forex market *efficiency* hypothesis and related CIP and UIP tests
    - the effectiveness of official forex market *intervention*
    - recent research on forex market *microstructure*
  - analyse Jeanne-Rose (2002) model with **noise traders**
    - describe its methodological approach and analytical set-up
    - derive and interpret its main theoretical results
    - discuss its policy implications and empirical relevance

Forex market efficiency

- closely related to the **efficient market hypothesis** in finance
  - in its *simplest* form, EMH is a **joint hypothesis** that, in an *aggregate* sense, the participants in the market
    1. hold ***rational*** **expectations**
    2. are **risk-*neutral***
  - EMH can be modified to account for **risk-*averse*** market participants: its 2nd part then becomes a model of equilibrium returns allowing for **risk *premia***
- Fama (1970) distinguished **3 forms** of market efficiency
  1. **weak**: prices reflect all the information contained in *past* prices
  2. **semi-strong**: prices reflect all *publicly* available information
  3. **strong**: prices reflect *all* information possibly known
- **academic interest** is related to
  - the **information content** of financial market *prices*
  - the implications for ***social*** **efficiency**
- **tests** traditionally involved interest parity conditions: CIP and UIP

Testing CIP => holds

- if a financial – or the *forex* – **market** is **efficient**, then:
  - prices should *fully* reflect information available to market participants
  - it should be *impossible* for a trader to earn excess return by speculation
- CIP, *ignoring* transaction costs: $\frac{F_{t,k}}{S_t} = \frac{1+\iota_{t,k}}{1+\iota^*_{t,k}}$
- CIP, in *logarithmic* approximation: $f_{t,k} - s_t = \iota_{t,k} - \iota^*_{t,k}$
- **2 approaches** have dominated *empirical* research on CIP

1. **neutral-band analysis**: Frenkel and Levich (1975, 1977)
   - compute *actual deviations* from CIP
   - check if these "significantly" differ from zero, with "significance" of departures w.r.t. a neutral (no profit) band *determined* by **transaction costs**
   - ask how often these observations fall *outside* the neutral band? => 0% for Euro-currency rates (CIP fully holds) and 20% for TBills (CIP roughly holds)
2. **regression analysis**, *abstracting from* transaction costs (if $\alpha=0$ and $\beta=1$, CIP holds): $f_{t,k} - s_t = \alpha + \beta\left(\iota_{t,k} - \iota^*_{t,k}\right) + \epsilon_t$

Testing UIP => does not hold

- UIP: the *basic* relationship used to asses forex market efficiency
- UIP, in *logarithmic* approximation: $E_t[s_{t+k}] - s_t = \imath_{t,k} - \imath^*_{t,k}$
- 1st UIP **tests**: for **randomness** in exchange rate *changes*: *only if*
  1. the NIR differential is identically equal to a *constant*, $\imath_{t,k} - \imath^*_{t,k} \equiv const$
  2. expectations are *rational*

  does the UIP eq. above imply a *random walk* in the exchange rate (with *drift* if the constant is *non-zero*): $E_t[s_{t+k}] = const + s_t$
- most often, tests of UIP have applied **regression analysis** to the spot and forward exchange rates
  - assuming CIP, UIP implies: forward premium = expected NER depreciation
  $$E_t[s_{t+k}] - s_t = f_{t,k} - s_t$$
  - under RE, the *expected* change in NER should differ from the *actual* change only by a RE *forecast error* => *β=1* in:
  $$s_{t+k} - s_t = \alpha + \beta[f_{t,k} - s_t] + \epsilon_{t+k}, \quad E_t[\epsilon_{t+k}] = 0$$

Reasons why UIP may not hold

1. **risk-*averse* agents** (vs 1st component of EMH, risk *neutrality*)
2. **failure**, in some sense, of ***R*E** (2nd component of EMH)
   1. *rational bubbles*: may occur because of multiple RE equilibria in addition to the “fundamentals” solution
   2. regime shifts and *rational learning* in the forex market: Lewis (1989 a, b)
   3. the *peso problem*: Rogoff (1979)
   4. *inefficiencies in information processing* => survey data studies: Bilson (1981)

- **to sum up**
  - data have persistently rejected the simple risk-neutral forex market efficiency hypothesis tested via UIP
  - due to problems with *both* assumptions underlying the joint EMH, as confirmed by survey data, namely risk *neutrality* and *rational* expectations

Official forex intervention under float <=> exchange rate management

- **definition:** authorities buy or sell foreign currency, normally against the national currency, with the objective to affect the (current) exchange rate
- of crucial **policy importance** => a huge *theoretical* and *empirical* literature
- substantial and ongoing **controversy** on questions like (i) whether, (ii) by what means, (iii) by how much and (iv) for how long the authorities can affect the exchange rate through intervening in the forex market
- **rationale**
  - **"wrong rate"** argument: under float, an inefficient forex market may tend to generate the "wrong" exchange rate, which implies *ex ante* abnormal returns, rather than the "correct" rate, defined as corresponding to economic fundamentals
  - **information set mismatch**: some information available to, and used by, market participants may be *inaccurate* or *misleading* in comparison to the information set of the authorities
  - **offsetting temporary disturbances**: e.g., exchange rate overshooting or cross-country policy interdependence
  - **adjustment-smoothing** argument: smoothing the adjustment process of exchange rates from *short* run values to *long* run values

Official forex intervention: types, profitability, data

- **types**
  1. non-sterilised vs **sterilised**: simultaneously or with a very short lag, the authorities take action to offset, i.e., “sterilise”, the effects of a change in official foreign asset holdings on the domestic monetary base (recall lecture 1)
  2. public (announced) vs secret
  3. internationally coordinated (concerted) vs non-coordinated
- **profitability:** *in general* and *in the long run*, central banks do make *profits* from intervening in the foreign exchange market
- **data:** despite monetary statistics, very *difficult* until recently to collect data on official intervention *at reasonable frequencies*

Official forex intervention: channels, effectiveness, feedback rules

- **channels**
  1. **portfolio balance** (adjustment) **channel**: PBM (lecture 3)

     investors *rebalance* their portfolio among assets in various currencies and countries on the basis of their relative expected returns
  2. **signalling** (policy intentions) **channel**: Mussa (1981)

     intervention affects NER by providing the market with *new relevant information* under the implicit assumptions that
     - authorities have *superior* information to other market participants
     - they are *willing to reveal* this information by actions in the forex market
- **effectiveness** of (sterilised) official forex intervention
  - strong consensus exists that *non-sterilised* FX intervention acts like monetary expansion/contraction and is rather *successful* in affecting NER
  - the effectiveness of *sterilised* intervention is very *controversial*
  - *overall*, the more recent literature suggests a significant *signalling effect* of official intervention on both the level and the change of exchange rates
- **central bank (policy) reaction functions**: theory and empirics

Forex market microstructure: approach illustrated by Jeanne-Rose (2002) model

- **objective**

  "to provide a theoretical framework for the policy-maker's view of fixed exchange rate regimes as shelters against speculative noise", JR02, p. 558
- model consists of *two components*, or blocks, each taken from a disparate part of economic theory
  - **macroblock**
    - macroeconomic theory of **exchange rate determination** => macroeconomic fundamentals
    - the conventional **monetary model** of the exchange rate with *flexible* prices, **augmented** by *portfolio* considerations
  - **microblock**
    - the **noise trading** approach to *asset price volatility* => **microstrucure**
    - the well-known **model** of noise trading developed by De Long, Shleifer, Summers and Waldmann (1987: NBER WP, 1990: JPE)
  - "As in chemistry, we make the experiment illuminating by combining two components that are as pure (uncontaminated by tangential complications) as possible." JR02, pp. 541-542

Jeanne-Rose (2002) model: macroblock

- **money market equilibrium** is posited in *H* and in *F*
  - assuming *simple* real MDFs
  - with NIR as the *sole* argument

$$m_t - p_t = -\alpha \iota_t, \qquad m_t^* - p_t^* = -\alpha \iota_t^*$$

  - and the *same sensitivity* of RMBs to changes in NIR
- **perfectly flexible prices**
  - with *PPP* satisfied *on average*: $s_t = p_t - p_t^* + \epsilon_t$
  - because ϵ is an *i.i.d. normal* shock
- so **NER** is

$$s_t = \overbrace{p_t}^{m_t + \alpha \iota_t} - \overbrace{p_t^*}^{m_t^* + \alpha \iota_t^*} + \epsilon_t = (m_t - m_t^*) + \alpha(\iota_t - \iota_t^*) + \epsilon_t$$

Jeanne-Rose (2002) model: exogenous variables

- to better focus on the impact of *policy changes* in the *domestic* country, it is assumed that *F* is in a **steady state**
  - with *constant* money supply, price level and interest rate
  - accordingly, the time index is dropped for these *F* variables
  - the *log* of *F* price level is then *normalised* to *zero*: $p_t^* = 0$
- domestic (i.e., *H*) **money supply** is assumed to be
  - an *exogenous* policy variable
  - and to follow a stochastic *i.i.d. normal* process *centred* on $\overline{m}$
  - as would be appropriate if the exchange rate *floats freely*

Jeanne-Rose (2002) model: risk averse investors and risk premium

- (domestic-country) interest rate is determined by equilibrium in **international bonds market**
- **investors** in that market are assumed
  - to care about the return of their portfolio measured in *real* terms, or – equivalently – in terms of the *foreign* currency since the *foreign* price level is *constant*
  - to be risk-*averse* => require a risk *premium* to hold bonds denominated in the domestic currency since the exchange rate is *stochastic* (i.e., *float*)
- "One may think of the foreign country as the center of the international financial system, and of the domestic country as a small open economy at the periphery. For the sake of brevity and *couleur locale*, we shall sometimes call the domestic currency "peso" and the foreign currency "dollar" (although we do not wish to imply that our model is meant to work especially well for developing countries)." JR02, p. 543

Jeanne-Rose (2002) model: BoP and currency composition of *H* debt

- quantity of *H* external liabilities results, in equilibrium, from BoP
  - these can take the form of **bonds** in *either* currency
  - supply of bonds denominated in **peso** (HC) is the result from actions of the domestic *monetary* and *fiscal* authorities
  - in particular, from the respective **shares** of *peso* and *dollar* (FC) bonds on the *asset* side of central bank's B/S
- some assumption is now required to **endogenise** the *currency composition* of home country's external debt

  for analytical convenience: domestic authorities maintain the supply of peso bonds to intl investors at a *constant real* level $\overline{b}$

Jeanne-Rose (2002) model: **microblock**

- forex traders modelled as overlapping generations of investors who
  - live for *two* periods and allocate their portfolio b/n peso- and dollar-denominated one-period *nominal* bonds in the *first* period of their life
  - have the **same** *endowments* and *tastes*
- **differ** in their ability to trade in the *peso*-bond market
  - **"informed" traders** are able to form *accurate* (i.e. *rational*) *expectations* on risk and returns *costlessly*
  - **noise traders** have *noisy* (i.e. *irrational*) *expectations* and have to pay an *entry cost* to invest in *peso* bonds – Lewis (1995: HBIE): tax issues, info problems,...
- each period a generation of N traders $j = 1,...,N$ is born
  - each individual trader j receives a real endowment of $\mathcal{W}$, which
    - can be invested in **dollar** bonds at **no cost**
    - traders **decide** whether to enter the peso-bond market: *entry* decision of trader j at time t is characterised by a *dummy* variable δ_t^j equal to 1 if trader j enters and 0 if she does not => **heterogeneity**: j indexes noise traders, no indexing means RE
    - traders **enter** the **peso**-bond market **only if** this choice increases their *expected* utility *conditional* on information available at t-1 before t shocks are revealed

$$\forall j,t \qquad \delta_t^j = 1 \Leftarrow E_{t-1}^j\left[U_t^j \mid \delta_t^j = 1\right] \geq E_{t-1}^j\left[U_t^j \mid \delta_t^j = 0\right]$$

Jeanne-Rose (2002) model: optimisation

- having entered the *peso*-bond market (i.e. once $\delta_t^j = 1$), trader j invests in *peso* bonds to **maximise** the *expected* utility of her *end-of-life* (period when *old*) wealth
- trader j's **portfolio allocation** problem at time t (period when *young*) is assumed to be

$$\max_{b_t^j} \; U_j^j = E_j^j\left[-\exp\left(-a\mathcal{W}_{t+1}^j\right)\right]$$

- where a is CARA and **end-of-life wealth** of j is given by

$$\mathcal{W}_{t+1}^j = (1+\imath^*)\mathcal{W} + \delta_t^j\left(b_t^j \rho_{t+1} - c^j\right)$$

- log-linearised **excess return** on *peso* bonds b/n t and $t+1$ is (cf UIP)

$$\rho_{t+1} \equiv \imath_t - (s_{t+1} - s_t) - \imath^*$$

Jeanne-Rose (2002) model **forex market microstructure**: informed traders

- **informed traders** are N_i in *number*, with $j = 1,...,N_i$
- remaining N_n traders $j = N_i+1,...,N$ are **noise traders**
- and clearly $N \equiv N_i + N_n$
- **informed traders** form their **RE** according to

$$E_t^j[\rho_{t+1}] = E_t[\rho_{t+1}], \qquad \forall j \leq N_i$$

$$var_t^j[\rho_{t+1}] = var_t[\rho_{t+1}], \qquad \forall j \leq N_i$$

Jeanne-Rose (2002) model **forex market microstructure**: noise traders

- authors follow the (standard) assumption that noise traders
  - perceive 2nd moments of returns correctly
  - but allow their perception of 1st moments to be affected by noise that is unrelated to economic fundamentals
- i.e., noise traders have ***irrationally volatile*** **expectations**
  - noise is **common** across traders, there is *no* private information: needed as the impact of noise on NER should *not cancel out* in aggregate (which is the case *only if* the noise has a component common across all noise traders)
  - furthermore, it is assumed for simplicity that **only** this component is present (addition of another, *idiosyncratic* component within the noise term would not change the essence of results, according to authors)
- formally, these assumptions are summarised as follows

$$E_t^j[\rho_{t+1}] = \overline{\rho} + \nu_t, \qquad \forall j > N_i$$

- where

$$var_t^j[\rho_{t+1}] = var_t[\rho_{t+1}], \qquad \forall j > N_i$$

  - $\overline{\rho}$ is the unconditional mean of the excess return (or average risk premium)
  - and the noise term v_t is a stochastic i.i.d. normal shock common across all noise traders and uncorrelated with m_t and ϵ_t

Jeanne-Rose (2002) model **forex market microstructure**: noise related to fundamentals

- Jeanne and Rose (2002) interpret the noise term as a **fad** that is *widespread* but *nonfundamental*
- **unlike** De Long, Shleifer, Summers and Waldmann (1990) on which they build, Jeanne-Rose (2002) assume
  - that noise traders do *not* make *systematic* errors in their prediction of excess returns
  - that the unconditional variance of the **noise** is *proportional* to the true unconditional variance of the **exchange rate**, thus linking the size of noise trader *errors* to *economic* (or *fundamental*) uncertainty

$$var[v] = \lambda var[s]$$

  - where λ is a *positive* coefficient

Jeanne-Rose (2002) model **forex market micro-structure**: individual heterogeneity of noise traders

- **individual heterogeneity** across *noise* traders introduced
  - through the *cost of* their *entry* into the *peso* bond market
  - such a heterogeneity can be *rationalised* in a number of ways: it may reflect the fact that
    - some traders inherit a larger stock of *knowledge* on the *home* economy
    - and so can afford to invest *less* in the acquisition of *information*
- authors then **order** noise traders by *increasing* entry cost

$$c^j = 0 \quad \text{for } j \leq N_i, \qquad c^j \geq 0 \quad \text{increasing with } j \text{ for } j > N_i$$

- the *entry cost* of noise traders is assumed **not too small**

$$\forall j > N_i, \quad c^j > \frac{1}{2a} \log(1 + \lambda)$$

Jeanne-Rose (2002) model: equilibrium

consists of stochastic processes for

- NER $\{s_t\}$
- risk premium $\{\rho_t\}$

and traders' decision rules $\left\{\delta_t^j\right\}$ and $\left\{b_t^j\right\}$ such that at each *t*

- δ_t^j satisfies the entry condition
- b_t^j is solution to the optimal portfolio allocation problem
- and market for domestic (peso) bonds is in equilibrium:

$$\overline{b} = \sum_{j=1,\dots,N} \delta_t^j b_t^j$$

Jeanne-Rose (2002) model: solution method

- the equilibrium in the previous slide is **difficult to determine**
  1. since it involves entry decisions by a set of *heterogeneous* agents
  2. in a *stochastic* environment
- Jeanne and Rose (2002) exploit the **assumption** that
  1. the driving **shocks** are **i.i.d.**, which suggests that
  2. the set of equilibrium individual decisions take a **simple form**
- they thus solve the model with a **"guess-and-verify"** technique
  1. *first postulating* its properties
  2. *then checking* that they are satisfied
- they **conjecture** that
  1. NER fluctuations are **i.i.d.** *around an average level* $\overline{s}$
  2. *all* informed + **constant** number of *noise* traders, *n*, enter peso-bond market
- they **characterise the equilibrium** in *two steps*
  1. determine equilibrium NER, taking the number of noise traders as given
  2. then endogenise the number of noise traders by using the entry condition

Jeanne-Rose (2002) model: solution with exogenous number of noise traders (I)

- in equilibrium the domestic interest rate and the risk premium are i.i.d. around average values $\overline{\rho}$ and $\overline{\iota}$
- hence, the average risk premium is $\overline{\rho} = \overline{\iota} - \iota^*$,
- which, taking the expectation of NER equation, implies $\overline{s} = \overline{m} - m^* + \alpha\overline{\rho}$ i.e. a higher average interest rate differential, by decreasing the demand for *H* relative to *F* money, leads to domestic currency depreciation
- the risk premium is determined in equilibrium in the market for peso bonds
  - if the excess return on these bonds is normally distributed (in addition to being i.i.d., as already assumed), which is shown to be true in equilibrium below,
  - it is well-known – recall lecture 1 – that maximising the objective written down earlier is equivalent to maximising the mean-variance objective function

$$E_t^j[\mathcal{W}_{t+1}] - \frac{a}{2} var_t^j[\mathcal{W}_{t+1}]$$

  - and individual trader *j*'s demand for peso bonds is given by $b_t^j = \dfrac{E_t^j[\rho_{t+1}]}{a \quad var_t^j[\rho_{t+1}]}$

Jeanne-Rose (2002) model: solution with exogenous number of noise traders (II)

- **equality of demand and supply** in peso-bond market implies that

$$N_i \frac{E_t[\rho_{t+1}]}{a \quad var_t[\rho_{t+1}]} + n \frac{\overline{\rho} + \nu_t}{a \quad var_t[\rho_{t+1}]} = \overline{b}$$

$$N_i E_t[\rho_{t+1}] + n(\overline{\rho} + \nu_t) = \overline{b}\, a \quad \underbrace{var[s]}_{\text{known constant}}$$

- taking the expectation of the above expression at *t-1* gives the **average risk premium**

$$E_{t-1}\{N_i E_t[\rho_{t+1}]\} + E_{t-1}\{n(\overline{\rho} + \nu_t)\} = E_{t-1}\left\{a \overline{b} var[s]\right\}$$

$$N_i E_{t-1}[\rho_{t+1}] + n(\overline{\rho} + E_{t-1}[\nu_t]) = a \overline{b} var[s]$$

$$N_i \overline{\rho} + n(\overline{\rho} + 0) = a \overline{b} var[s]$$

$$\overline{\rho} = a \frac{\overline{b}}{N_i + n} var[s]$$

Jeanne-Rose (2002) model: solution with exogenous number of noise traders (III)

- it is shown in lecture 9 how we can now derive:

$$s_t - \overline{s} = \frac{1}{1+\alpha}\left(m_t - \overline{m} + \epsilon_t - \alpha \frac{n}{N_i}\nu_t\right)$$

- taking the var of equilibrium NER eq. and using the var relation to substitute out the var of the noise closes the characterisation of equilibrium with an expression for **exchange rate variability**

$$var[s] = \frac{var[m+\epsilon]}{(1+\alpha)^2 - \lambda\alpha^2\left(\frac{n}{N_i}\right)^2}$$

- noise traders have two *counteracting* roles in the model: they both (a) *create* risk: $\overline{\rho}\uparrow$; and (b) *share* risk: $\overline{\rho}\downarrow$ (previous slide)
- thus, the impact of the extra noise traders on the *equilibrium risk premium* is **nonmonotonic (ambiguous)**: <u>Fig. 1, p. 549, in Jeanne and Rose (2002)</u>

Jeanne-Rose (2002) model: main result with endogenous entry of noise traders

- **endogenising entry**: a noise trader *j* enters if gross benefit > cost:

$$GB(\overline{\rho}, var(s)) = \frac{1}{2a(1+\lambda)} \frac{\overline{\rho}^2}{var(s)} + \frac{1}{2a} \log(1+\lambda) \geq c^j$$

- **noise traders create NER volatility** if they choose to enter the domestic (peso-) bond market in order to diversify their portfolio
  - they benefit from holding peso-bonds but
  - pay a cost for entering the market and
  - create undesirable NER volatility
- for a range of fundamental macroeconomic volatility
  - the model generates **multiple equilibria under float** (circularity) but
  - there is **another equilibrium with** less noise trading and a **more stable NER**
- with a *stable* (*not* necessarily *fixed*) NER *regime* (as we discuss next)
  - **authorities** *can coordinate activity* to the “good” equilibrium
  - exchange rate policy works by *affecting the composition of forex market*, not simply by the traditional mechanism of subordinating MonPol to a NER target

Jeanne-Rose (2002) model: policy implications

- **government loss function:** to explore policy formally
- **(pure) float:** constrained optimisation problem (z_t is a composite shock)

$$(P)\begin{cases} \min L \equiv \omega var(p) + (1-\omega) var(\iota) \\ (p_t - \overline{p}) + (\iota_t - \overline{\iota}) = z_t \end{cases} \qquad z_t \equiv -\left(\epsilon_t + \frac{n}{N_i}\nu_t\right)$$

- **stable NER regime:** *new constraint* in optimisation!

$$(P')\begin{cases} \min L \equiv \omega var(p) + (1-\omega) var(\iota) \\ (p_t - \overline{p}) + (\iota_t - \overline{\iota}) = z_t \\ var(s) \leq \upsilon \end{cases}$$

- **main result**
  - it is optimal to adopt an objective of NER stability *as soon as* a pure float attracts noise traders
  - reducing NER volatility may *dominate* sacrifice of monetary autonomy!

Jeanne-Rose (2002) model: empirics

- difficult to directly test the model
- hence, **3 indirect "tests" and** their **findings**

  under pure float

  - *more* noise, i.e., higher forecast *spread* (*FT Currency Forecaster* data, "high forecast" – "low forecast")
  - *larger* deviations from UIP
  - *higher* volume of forex markets (BIS data set)

  than under peg (as proxy for stable NER regime)

Concluding wrap-up

- **What have we learnt?**
  - summarise and critically assess the **literature on**
    - forex market *efficiency* and related CIP and UIP tests
    - official forex market *intervention*
    - forex market *microstructure*
  - analyse Jeanne-Rose (2002) model with **noise traders**
    - describe its methodological approach and analytical set-up
    - derive and interpret its main theoretical results
    - discuss its policy implications and empirical relevance
- **Where we go next**: to an evaluation / rethinking of the course and its usefulness for future courses / career