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Solution to written exam for the M. Sc in Economics International Finance

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1. **Which of the following statements are correct? Remember to provide a brief explanation.**

   These questions relate to the learning objectives: Describe how the foreign exchange market is organized and how trades take place in the interbank and the retail segments of the market; describe and use microstructure based models to analyze price determination on the foreign exchange market and summarize the empirical evidence on these models; describe the portfolio balance model and be able to use this model to analyze the effects of monetary and fiscal policy on the exchange rate.

   (a) Wrong! According to the Portfolio Balance Model, there is an effect on both the exchange rate and the interest rate when agents swap foreign bonds for domestic bonds. The reason is that foreign and domestic bonds are not perfect substitutes (they are not equally risky).

   (b) Wrong! According to the Portfolio Shift Model, it is the unexpected part of order flows that convey price-relevant information to dealers. At the same time we know (also according to the Portfolio Shift Model) that interdealer order flows depend on the public pre-existing holdings of foreign exchange that are correlated with lagged foreign exchange quotes. This implies that it is possible that exchange rates to some extent can be predicted by order flows.

   (c) Wrong! Order flow is defined as the difference between purchase and sell orders (positive or negative) initiated by customers during a trading period measured in units of a currency. Trading volume (or turnover) measures the value of all trading in exchange rates during a trading period. Transaction volume is the absolute value of the order flow.

2. **Exchange rates and macro data releases**

   This question relates to the learning objective: describe and explain how macro data releases affect exchange rates and summarize the empirical evidence.

(a) The following equation is stated in the problem:

$$\delta_t = \mathrm{E}\left[\Delta s_{t+1} \mid \Omega_t\right] + \hat{r}_t - r_t. \tag{1}$$

here δ is the (time-varying) risk premium which is a function of the expected change in the nominal exchange rate ($\mathrm{E}\left[\Delta s_{t+1}\right]$) given the common information set available to all market participants at time t (Ω_t), r_t is the home interest rate and $\hat{r}_t$ is the foreign interest rate. This expression follows directly from UIP under the assumption that domestic and foreign bonds are not perfect substitutes. The logic behind this equation is that the exchange rate will respond immediately to macro data releases if these releases induce a change in the interest differential and/or the risk premium; if macro data releases induce a revision of the expected future interest rate differential and/or the risk premium; and if there is a revision of the expected long-run real exchange rate.

(b) Show that this equation can be written as

$$\varepsilon_t = \mathrm{E}\left[\varepsilon_{t+1} \mid \Omega_t\right] + \eta_{t,t+1} \tag{2}$$

where

$$\eta_{t,t+1} = \left(\hat{r}_t - \mathrm{E}\left[\Delta \hat{p}_{t+1} \mid \Omega_t\right]\right) - \left(r_t - \mathrm{E}\left[\Delta p_{t+1} \mid \Omega_t\right]\right) - \delta_t$$

under the assumption that the real exchange rate is $\varepsilon_t = s_t + \hat{p}_t - p_t$ and the real interest rates are $r_t - \mathrm{E}\left[\Delta p_{t+1} \mid \Omega_t\right]$ and $\hat{r}_t - \mathrm{E}\left[\Delta \hat{p}_{t+1} \mid \Omega_t\right]$.

Let the real exchange rate be

$$\varepsilon_t = s_t + \hat{p}_t - p_t$$

and the real interest rates as $r_t - \mathrm{E}[\Delta p_{t+1} \mid \Omega_t]$ and $\hat{r}_t - \mathrm{E}[\Delta \hat{p}_{t+1} \mid \Omega_t]$ and insert these relations into the expression for the risk premium such that

$$\delta_t = \mathrm{E}\left[\Delta \varepsilon_{t+1} \mid \Omega_t\right] + \left(\hat{r}_t - \mathrm{E}\left[\Delta \hat{p}_{t+1} \mid \Omega_t\right]\right) - \left(r_t - \mathrm{E}\left[\Delta p_{t+1} \mid \Omega_t\right]\right)$$

which can be rewritten as

$$\varepsilon_t = \mathrm{E}\left[\varepsilon_{t+1} \mid \Omega_t\right] + \eta_{t,t+1}$$

where

$$\eta_{t,t+1} = \left(\hat{r}_t - \mathrm{E}\left[\Delta \hat{p}_{t+1} \mid \Omega_t\right]\right) - \left(r_t - \mathrm{E}\left[\Delta p_{t+1} \mid \Omega_t\right]\right) - \delta_t$$

(c) Substitute $\varepsilon_t = \mathrm{E}\left[\varepsilon_{t+1} \mid \Omega_t\right] + \eta_{t,t+1}$ forward such that

$$\varepsilon_t = \eta_{t,t+1} + \sum_{j=1}^{\infty} \mathrm{E}\left[\eta_{t+j,t+j+1} \mid \Omega_t\right] + \underbrace{\lim_{h\to\infty} \mathrm{E}\left[\varepsilon_{t+h} \mid \Omega_t\right]}_{\varepsilon_t^{\infty}}$$

Next, using this equation we can compute the unexpected variation in the real exchange rate at some point between t and before the start of period $t+1$, i.e., point $t+\epsilon$ where $\epsilon < 1$. We also assume that the price level is unchanged such that any variation in the real exchange rate reflects variation in the spot rate, i.e., $s_{t+\epsilon} - s_t = \varepsilon_{t+\epsilon} - \varepsilon_t$. We then obtain

$$\varepsilon_{t+\epsilon} - \mathrm{E}[\varepsilon_{t+\epsilon} \mid \Omega_t] = \eta_{t+\epsilon,t+1} - \mathrm{E}[\eta_{t+\epsilon,t+1} \mid \Omega_t] +$$

$$\sum_{j=1}^{\infty} \{\mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_t]\} + \varepsilon^{\infty}_{t+\epsilon} - \varepsilon^{\infty}_{t} \tag{3}$$

If we also assume (as was stated in the problem) that the interval $[t, t+\epsilon]$ covers just a few minutes then variations in nominal and real exchange rates mirror one another because retail prices are likely to be constant over this time interval. Under this assumption we can express the change in the spot rate as

$$s_{t+\epsilon} - s_t = \varepsilon_{t+\epsilon} - \varepsilon_t = \mathrm{E}[\varepsilon_{t+\epsilon} - \varepsilon_t \mid \Omega_t] + \varepsilon_{t+\epsilon} - \mathrm{E}[\varepsilon_{t+\epsilon} \mid \Omega_t]$$

Substituting for $\varepsilon_{t+\epsilon} - \mathrm{E}[\varepsilon_{t+\epsilon} \mid \Omega_t]$ above we obtain

$$s_{t+\epsilon} - s_t = \{\eta_{t+\epsilon,t+1} - \mathrm{E}[\eta_{t+\epsilon,t+1} \mid \Omega_t]\} +$$

$$\sum_{j=1}^{\infty} \{\mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_t]\} + u_{t+\epsilon}$$

where $u_{t+\epsilon} = \mathrm{E}[\varepsilon_{t+\epsilon} - \varepsilon_t \mid \Omega_t] + \varepsilon^{\infty}_{t+\epsilon} - \varepsilon^{\infty}_{t}$.

This equation provides a decomposition of high-frequency changes in the log spot rate that must hold in any model. According to this model, a macro data release affects the spot rate via:

1. unexpected changes in the current risk-adjusted real interest differential ($\{\eta_{t+\epsilon,t+1} - \mathrm{E}[\eta_{t+\epsilon,t+1} \mid \Omega_t]\}$)
2. revisions in the forecasts for future differentials ($\sum_{j=1}^{\infty} \{\mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_t]\}$)
3. changes in long-term real-exchange rate expectations ($\varepsilon^{\infty}_{t+\epsilon} - \varepsilon^{\infty}_{t}$). Note that this component is zero if PPP holds in the long-run.

Data releases may well contain new information on current and future macro variables but they need not affect spot rates if the information they convey has offsetting effects on the risk-adjusted interest differentials.

- When central banks conduct monetary policy by controlling short-term interest rates, most data releases (other than policy changes) have negligible effects on current real interest rates. Suppose that the central bank announces an increase in the interest rate and that the market did not anticipate this change. There will be an unexpected increase in the short-term interest rate ($r_{t+\epsilon} - \mathrm{E}[r_{t+\epsilon} \mid \Omega_t] > 0$). It may be that market participants revise their expectation about future inflation, they expect inflation to rise and this rise may match the increase in the short-term interest rate such that $r_{t+\epsilon} - \mathrm{E}[r_{t+\epsilon} \mid \Omega_t] = \mathrm{E}[\Delta p_{t+1} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\Delta p_{t+1} \mid \Omega_t]$. If this is the case, there is no unexpected change in the risk-adjusted interest rate differential $\eta_{t+\epsilon}$. If the expectation about future interest rates is mirrored by a change in inflation expectations then $\mathrm{E}[\eta_{t+i} \mid \Omega_{t+\epsilon}] = \mathrm{E}[\eta_{t+i} \mid \Omega_t]$ for $i \geq 1$. Then there will be no response in spot rates to unexpected monetary policy announcements.

- Data releases may contain new information on current and future macro variables, but it is not always the case that the spot rate will adjust. Most macro news (other than monetary policy announcements) do not affect current real interest rates implying that changes in the risk premium and/or revisions in expectations about the future course of real interest rates are important. This works through the component $\sum_{j=1}^{\infty}\{\mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_t]\}$.
- Absent any restrictions on the expected response of future interest rates and inflation to the new information in the data release, the exchange-rate effects of a macro data release are theoretically ambiguous. The following examples illustrate (it is not required that answers include these examples).
  - Example 1: If a data release on GDP lead market participants to believe that that the central bank will tighten future monetary policy,$\sum_{j=1}^{\infty}\{\mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_t]\} < 0$ so the exchange rate should appreciate.
  - Example 2: If market participants believe that future inflation will increase more quickly than the central bank will raise the interest rate $\sum_{j=1}^{\infty}\{\mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\eta_{t+j,t+j+1} \mid \Omega_t]\} > 0$ so the currency should depreciate.
- The equation above also has implications for the duration of the exchange rate response to data releases. By definition

$$\mathrm{E}[\Delta\varepsilon_{t+1+i} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\Delta\varepsilon_{t+1+i} \mid \Omega_t] = -(\mathrm{E}[\eta_{t+i} \mid \Omega_{t+\epsilon}] - \mathrm{E}[\eta_{t+i} \mid \Omega_t])$$

  for $i > 0$, so any data release that leads market participants to revise their forecasts for the future risk-adjusted real interest differential also changes their forecasts for the rate of real depreciation after the release takes place. Thus, spot rates may respond immediately to the release of macro data, but their initial response can differ from their total long run response.

3. This question relates to two learning objectives: describe and use microstructure based models to analyze price determination on the foreign exchange market and summarize the empirical evidence on these models; describe the channels by which central bank

intervention can affect the exchange rate, summarize the empirical evidence on these channels and describe the portfolio balance model and be able to use this model to analyze the effects of monetary and fiscal policy on the exchange rate. The model discussed in the question is a Portfolio Shift Model which in this case is used to analyze the effects of secret central bank intervention.

(a) A secret intervention can be defined as "foreign exchange operations that are not disclosed to the market participants (at least not contemporaneously)" The Fed and Bundesbank (ECB) and other central banks have adopted more transparent policies but Bank of Japan still relies on secret interventions. The question is if it is possible to keep interventions secret. The answer is yes! The central bank can decide not to reveal that they intervened and they may use ways to hide interventions from foreign exchange brokers. Central bank trading can be mistakenly viewed as private trades. Note that if interventions are secret, then there is no signal to the market that could change market expectations, the signalling channel breaks down.

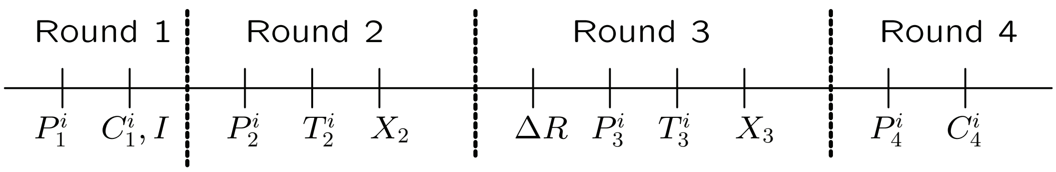
There are in principle three arguments for secret interventions:

- Minimize the effects of an unwanted intervention operation. In some countries, for example the US, the decision to intervene is taken outside the central bank. The central bank must then exwecute the intervention regardless of whether the bank object to the decision or not. The central bank then could decide to use secret intervention in order to minimize the effects (the bank only relies on the portfolio balance channel, there is no signalling effect). It could also be the case that the central bank considers the intervention as inconsistent with other goals of monetary policy.
- Perceived risk and volatility in the FX market. It is risky for the central bank to publicly announce an intervention when the market situation is uncertain and there is a high volatility in particular if the banks reputation is not strong. It is possible, in such a situation, that the market participants may not be believed. Therefore, it may be optimal for the bank to use a secret intervention.
- Portfolio adjustment argument. It may be that the central bank intervene only in order to adjust its holdings of foreign assets and not as a signal of future policy changes. An announcement could in this case lead to increased uncertainty on the market. Thus, it may be optimal in this case to use secret interventions.

Recent empirical evidence suggests that, the proportion of secret interventions is much lower for coordinated operations than for unilateral interventions, and there is an increased frequency of secret operations in the FX market, in particular on the YEN–USD market. But this implication is not supported by empirical evidence. According to a recent central bank survey, most central banks agree that intervention affects exchange rates through the signalling channel, not the portfolio balance channel. They also regard consistency of policies and reputation as important. Since central banks use secret interventions, this implies that they disregard the signalling channel and relies on the portfolio channel, which constitutes a puzzle. At the same time they are neutral or agree with the three arguments above on the reasons for keeping an intervention secret.

(b) Lyons and Evans extend the standard microstructure model to also include central bank interventions. In order to exclude signaling, they focus on secret sterilized interventions. This implies that interventions are equivalent to public trades since market participants cannot distinguish between order flows initiated by the central bank and order flows initiated by the public. The focus is therefore on the portfolio balance channel and the effects of secret interventions. Their starting point is that at the dealer level, dealers must be compensated for holding risky positions. This requires a temporary risk premium which is reflected by price adjustments. It is temporary since dealers may not require a risk premium once they share overnight risk with the public. This is similar to the inventory effects on prices and is not present in standard macro models. At the market level, market participants must be compensated for holding positions that they would not otherwise hold. A risk premium is required here also and therefore implies price adjustments. These price adjustments are persistent since risk is shared globally. In macro models this effect is the portfolio balance effect.

There are two assets in the model, one riskless and one risky, the exchange rate. There are N dealers indexed by i and a continuum of customers (the public). Dealers and customers have the same utility function (negative exponential utility) defined over periodic wealth. Each day there is a payoff on foreign exchange ΔR interpreted as the flow of public macroeconomic information, e.g., interest rate changes. The trading day is divided into four segments, not three as in their standard model. A trading day is illustrated in the graph below



- Round 1: Dealers trade with customers and the central bank. At the beginning of the day, dealers quote a scalar price to the public and to the central bank. This price is identical, for arbitrage reasons, across all dealers ($P_1^i = P_1$). This price is conditioned on all information available to dealers.

Each dealer then receives net customer orders C_1^i. As before $C_1^i < 0$ is a net customer sale whereas $C_1^i > 0$ is a net customer purchase. These orders represent portfolio shifts by the public and are not publicly observed. At the same time one dealer receives the intervention trade. I_t denotes the intervention on day t. If $I_t < 0$ then the central bank is selling and if $I_t > 0$ the central bank is buying. In order to hide the trades, the central bank randomly select one dealer and trade with this dealer via an agent. This implies that the intervention is kept secret. It is also assumed that interventions are sterilized. Therefore, there is no signaling effect. This further implies that interventions are uncorrelated to the daily payoffs ΔR.

- Round 2: Dealers trade among themselves to share inventory risk. Each dealer simultaneously and independently quotes a scalar price. For arbitrage reasons, this price is identical across all dealers, $P_2^i = P_2$. This price is observable and available to all dealers. T_2^i is net interdealer trade in round 2. At the end of Round 2, all dealers observe a noisy signal of the total interdealer order flow X_2. They cannot observe the order flow in Round 1, they learn more in Round 2 and observes the total interdealer order flow in Round 3 without noise. Interdealer trades in Round 2 generate signals of order flows that can be observed. Note that the interdealer order flow X_2 is the only public information revealed in Round 2, and is assumed to be correlated to the order flows in Round 1 $(C_1 + I)$ and therefore provide information about order flows in Round 1. $P_2 = P_1$ since no additional public information is observed from Round 1 trading, customer trades and central bank intervention are not publicly observed.
- Round 3: The payoff is realized and dealers trade again. At the start of Round 3, the payoff ΔR is realized. This payoff is publicly observable. Then dealers quote a new price $P_3^i = P_3$. This price is observable and available to all dealers. At the close of Round 3, all agents observe the interdealer order flow $X_4 = \sum_{i=1}^{N} T_3^i$. The change in prices from Round 2 to Round 3 must be driven by the order flow X_2 which serves as the information aggregation. Private information that each dealer receives from customers (and the central bank) is transmitted to other dealers. In the model, Evans and Lyons assume that the price change is proportional to the interdealer order flow X_2 which is observable. This is the temporary risk premium inducing dealers to hold risky positions intra-daily. A positive order flow induces a price increase since dealers are short (customer is buying and dealer is selling). The prices in Rounds 1 (and 2) and 3 are set such that dealers willingly absorb the demand from customers and the central bank realized at the beginning of the day but not publicly observed.
- Round 4: Dealers trade with customers to share overnight risk. In Round 4,

dealers share overnight risk with customers. Each dealer quotes a scalar price as before which is identical across all dealers, $P_4^i = P_4$. The price change must reflect: (1) the interdealer order flow X_3 reflecting Round 1 order flows since it doesn't include noise, (2) the payoff ΔR, and (3) the price change from Round 2 and 3, i.e., the interdealer order flow X_2 (a negative effect since this order flow partly reflects an intra-day risk premium which should dissipate by the end of the day). Note that all these are publicly observable! A positive order flow X_3 implies that the markets estimate of $C_1 + I$ from X_2 was too low. Customers are buying and dealers are selling creating a short position and therefore an increase in the price. At the price P_4, the public willingly absorbs the estimated demand from customers and the central bank. Dealers end the day with no net position

Common information arises at three points in time

- at the end of Round 2 (the order flow X_2),
- at the beginning of Round 3 (the payoff ΔR), and
- at the end of Round 3 (the order flow X_3).

The price quoted at the beginning of Round 4, P_4, reflects this information. The portfolio balance effect arises since interdealer order flows inform dealers about the initial portfolio shift $(C_1 + I)$ that must be absorbed by the public at the end of the day. This portfolio shift effect is the same regardless of whether it is initiated by a customer or the central bank. They both induce the same portfolio shift at the end of the day.