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Solutions to written exam for the M. Sc in Economics
Economics of Exchange Rates

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Number of questions: This exam consists of 2 questions.

1. **Exchange rate determination in classical macro models**

   This question relates to the following learning objectives. Knowledge: Describe and explain Covered Interest Rate Parity (CIP), Uncovered Interest Rate Parity (UIP), and Purchasing Power Parity (PPP) and be able to summarize the empirical evidence on international interest these parity conditions. Skills: Describe the main models of exchange rate determination (the Monetary approach to the exchange rate, Dornbusch overshooting model, the portfolio balance model and Lucas asset pricing model) and apply these models to analyze the effects of monetary and fiscal policy on the exchange rate, and summarize the empirical evidence on these models. Describe and apply Mundell-Fleming models to analyze the effects of economic policy under both flexible and fixed exchange rates.

   (a) Explain the underlying assumptions and predictions of the flexible-price monetary model, the sticky-price monetary model and the real interest rate differential model. Clearly point out the main differences between these models.

   Answer:

   Flexible-price monetary model (FPMM). Assumptions: flexible prices, PPP holds continuously, UIP holds (with or without risk premium), inflation expectations, and output is at its natural level and constant. No particular assumption about a small open economy.

   Sticky-price monetary model (SPMM). Assumptions: fixed prices, PPP holds in the long-run, not in the short-run, UIP holds (with or without risk premium), no inflation expectations, and output is demand determined.

   Real interest rate differential model: Same assumptions as in the SPMM model but adds inflation expectations, the long-run expected inflation differential affects the nominal exchange rate.

   Overshooting effect: Exists in SPMM but not in FPMM. Reason for overshooting is that PPP does not hold continuously since prices are sticky. There is also an overshooting effect in the real interest rate model. The reason for this is that rational

expectations hold for the exchange rate market but not for the goods market, prices are sticky. An unanticipated increase in the money supply leads to a fall in the domestic real interest rate since prices are initially constant but there is an expectation that the domestic price level will increase in the future.

(b) What is the empirical evidence on these three models?

Answer: FPMM: Usually wrong signs and insignificant parameters, the model is usually rejected. Frenkel (1976) supports the model using high inflation data (German hyperinflation during the 1920s) and some recent studies using data for flexible exchange rate regimes (early 1970's data) also support FPMM. Using data for the 1980's, the model performs not so well. SPMM: Same general results as for the FPMM, there are a few tests supporting the SPMM also. Real-interest rate model: Same general results, very often reject the model.

(c) Explain carefully what is meant by the disconnect puzzle and outline possible attempts to solve this puzzle.

Answer: Disconnect puzzle: The fact that the exchange rate seems to be only weakly, except in the long run, related to virtually any macroeconomic aggregates. The disconnect puzzle is related to the PPP puzzle, the fact that deviations from PPP are persistent (estimated half-life of deviations from PPP is about three to five years). This puzzle was first noted in empirical work by Meese and Rogoff in the ealry 1980s. They found that conventional models (FPMM and SPMM) cannot forecast satisfactorily the exchange rate, a random walk model always beat conventional exchange rate models. Recent studies seem to confirm this pattern, there are very few examples of studies where forecasts using conventional exchange rate model outperform a random walk model. The results in these studies are difficult to replicate using other sample periods. A number of potential solutions to this puzzle have been suggested, including time-varying parameters (using Lucas critique arguments), non-linear models but usually they fail to provide an explanation. One empirical regularity is that it is easier to forecast exchange rates for long horizons, even using PPP.

Possible reasons why it is difficult to forecast exchange rate movements in the short-run could be that investors behave differently, they don't react in a similar way to new information, agents are not all alike. Other explanations include the possibility that exchange rates are not only affected or determined by monetary policy as in our basic models, fiscal policy and the monetary-fiscal policy mix may also affect exchange rates. According to our models, exchange rates depend not only on present fundamentals but also future fundamentals, a fact that is not usually used in empirical tests of fundamental models, the "Peso problem": Even if the models are correct, it may be the case that an expected event does not materialize (this would affect the actual exchange rate but it may look as if the exchange rate moves in a way not predicted by our model), distinguishing between unanticipated and anticipated

shocks could be of importance, demand for money (one of the building blocks of the models above) may not be stable over time, it may also be the case that there is no money demand function (this is often contradicted by empirical evidence suggesting the opposite), real shocks may also be important, structural changes in financial markets, the emergence of new derivatives and so on may also explain the poor forecast ability of fundamental models. The main conclusion from the literature is that there seems to be a disconnect between exchange rate movements and fundamentals in the short-run but not in the long-run.

(d) Consider the following flexible-price monetary model where the money demand functions in the two countries are given by

$$m_t = p_t + \kappa y_t - \theta i_t \tag{1}$$

and

$$m_t^* = p_t^* + \kappa y_t^* - \theta i_t^*. \tag{2}$$

We also assume that PPP holds continuously

$$s_t = p_t - p_t^*. \tag{3}$$

Notation is standard. Use these relations and solve for the spot exchange rate. Interpret your result carefully. What are the predictions of the model?

Answer: Use the money demand functions (equations (1) and (2)) to solve for the price levels in the two countries and then insert into PPP. This allows us to express the nominal exchange rate as

$$s_t = (m_t - m_t^*) - \kappa (y_t - y_t^*) + \theta (i_t - i_t^*). \tag{4}$$

The interpretation is: An increase in m implies a depreciation (a rise in s), higher domestic output implies an appreciation, and a higher domestic interest rate leads to a depreciation. The reason for this prediction is that a higher domestic interest rate leads to higher inflation. Given that the real interest rate is constant this leads to a depreciation according to PPP. This can be seen if we use the Fisher equations $r_t = i_t - \Delta p_t$ and $r_t^* = i_t^* - \Delta p_t^*$ and insert these into the exchange rate equation such that

$$s_t = (m_t - m_t^*) - \kappa (y_t - y_t^*) + \theta (\Delta p_t - \Delta p_t^*).$$

Higher domestic inflation leads to a depreciated exchange rate under the assumption that the real interest rate is constant in which case the nominal interest rate increases in proportion to inflation.

(e) Assume now that UIP holds

$$i_t - i_t^* = \Delta s_{t+1}^e.$$

Show that this implies that

$$s_t = (1+\theta)^{-1} (m_t - m_t^*) - (1+\theta)^{-1} \kappa (y_t - y_t^*) + \theta (1+\theta)^{-1} s_{t+1}^e \tag{5}$$

Answer: UIP implies that $i_t - i_t^* = \Delta s_{t+1}^e$ which can be inserted into the exchange rate equation above which yields

$$s_t = (m_t - m_t^*) - \kappa (y_t - y_t^*) + \theta \Delta s_{t+1}^e \tag{6}$$

or rewritten as

$$s_t = (1+\theta)^{-1} (m_t - m_t^*) - (1+\theta)^{-1} \kappa (y_t - y_t^*) + \theta (1+\theta)^{-1} s_{t+1}^e \tag{7}$$

(f) Solve this difference equation. Interpret your result. How is the spot exchange rate determined?

Answer: Define the fundamentals $f_t = (m_t - m_t^*) - \kappa (y_t - y_t^*)$ implying that

$$s_t = \frac{1}{1+\theta} f_t + \frac{\theta}{1+\theta} s_{t+1}^e$$

Iterate forward and collect terms:

$$s_{t+1} = \frac{1}{1+\theta} \mathrm{E}[f_{t+1} \mid \Omega_t] + \frac{\theta}{1+\theta} \mathrm{E}[s_{t+2} \mid \Omega_t]$$

$$s_{t+2} = \frac{1}{1+\theta} \mathrm{E}[f_{t+2} \mid \Omega_t] + \frac{\theta}{1+\theta} \mathrm{E}[s_{t+3} \mid \Omega_t]$$

$$\vdots$$

Substitute forward and collect terms such that

$$s_t = (1+\theta)^{-1} \sum_{i=0}^{\infty} \left(\frac{\theta}{1+\theta} \right)^i \mathrm{E}_t \left[(m_{t+i} - m_{t+i}^*) - \kappa \left(y_{t+i} - y_{t+i}^* \right) \right] + \tag{8}$$

$$\lim_{i \to \infty} \left(\frac{\theta}{1+\theta} \right)^i s_{t+i}^e$$

The last term on the RHS is the bubble term. If we exclude bubbles, then this part goes to zero (which is the case since $\frac{\theta}{1+\theta} < 1$). The model states that the exchange rate at time t is equal to present and discounted future fundamentals.

2. **FX market micro structure**

This question relates to the following learning objectives. Knowledge: Describe how the foreign exchange market is organized and how trades take place in the market. Describe the institutional features of the foreign exchange market products (spot and forward contracts) and be able to distinguish between speculation and arbitrage. Describe the types of risks that foreign exchange traders face and how these can be managed. Skills: Describe and apply microstructure based models to analyze price determination on the foreign exchange market and summarize the empirical evidence on these models.

(a) Explain how the FX market is organized and who the main market participants are?

Answer: Organization: Currencies are traded over the counter (OTC) between market makers (A bank that quotes bid and ask prices and guarantees to buy and sell a minimum volume in one or several currency pairs) and customers. There is no regulated market place. There are a number of risks involved in trading that must be handled. Market maker risks involve (i) liquidity risk (the bank is forced to match orders and is exposed to the risk that there is not enough liquidity in the market), (ii) market risk (value of position in a currency vary over time), and (iii) credit risk; counterparty (risk of counterparty's default) and settlement risk (the risk that a bank pays the currency it sold but does not receive the currency bought including counterparty default, operational problems, market liquidity constraints). It is not possible to remove counterparty risk but settlement risk is handled through Continuous Linked Settlement (CLS) system which exists for 17 major currencies and is used by market participants. The FX market is decentralized and fragmented.

The FX market can be divided into two different and distinct markets, the retail market where customers trade with commercial and investment banks, and the interbank market where banks trade with each other both directly and through brokers. The interbank market can be divided into two parts; the *direct* market (bank–to–bank) and the *indirect* or brokered market (bank–to–broker). The direct market is a double–auction (both buy and sell prices are specified) and open–bid market (all offers to buy or sell at a specified price are announced to all market participants). The indirect (or brokered market) is a single–auction (either buy or sell prices are quoted), closed–order–book or limit–book (offers to buy or sell a specified quantity up to a maximum price or above a minimum price only known to agents placing the order of either buying or selling a certain amount of currency against another currency at a specified rate of exchange).

Market participants: (i) retail clients (customers): businesses, international investors, multinational corporations and others need foreign currency for their businesses (they do not directly buy or sell foreign currencies only place buy/sell orders with commercial banks); (ii) commercial banks carry out buy and sell orders and buy and sell currencies on their own account (portfolio adjustments), banks deal either directly with other banks or through foreign exchange brokers; (iii) foreign exchange brokers collect buy and sell orders from commercial banks and for most currencies with low transaction costs, they are located at each financial center; and (iv) Central Banks intervene on the foreign exchange market to buy and sell its own currency in order to influence the value of the domestic currency.

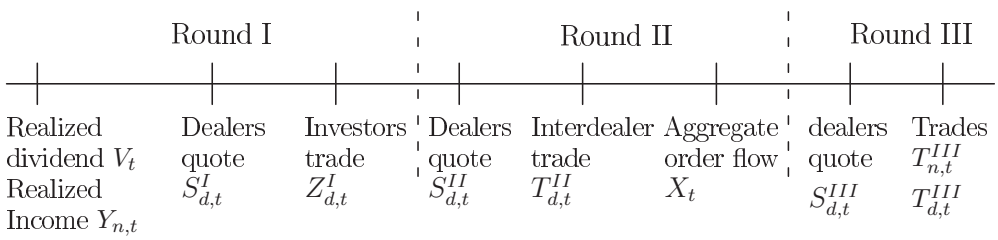
(b) The Portfolio Shift Model attempts to model the main features of the FX market. This model identifies two main drivers of spot exchange rates. Discuss these drivers.

Answer: The Portfolio Shift model identifies two drivers of spot exchange rates: Common Knowledge information transmitted via macroeconomic data releases and

other new announcements, and dispersed information transmitted via aggregate interdealer order flow. Common knowledge will immediately be incorporated into quoted prices. Dealers interpret the common knowledge differently. New information which is common knowledge can be the source of dispersed information, i.e., be a source of customer order flows. Common knowledge may operate both via the direct channel (common knowledge to all dealers) and via the indirect channel (dispersed information) through order flows. Customer orders on the retail market provide private information to the dealers (dispersed information) and these orders are generated by different types of agents and for different reasons, for example for speculation or risk–management.

(c) Outline the Portfolio Shift Model and explain how the spot exchange rate is determined.

Answer: The portfolio shift model describes how trades on the retail and the interbank markets relates to the spot exchange rate. Main assumptions are: two assets, one risky asset (the foreign exchange) and one risk–free asset with a daily return, there are D risk–averse dealers indexed by d, there is a continuum of risk–averse investors (customers) indexed by $n \in [0, 1]$, all trading decisions are motivated by the desire of each agent to maximize expected utility, neither dealers nor investors are motivated to trade for information. The idea is to explain how dispersed information available to customers is transmitted to dealers through order flows on the retail market and how dispersed information is aggregated through order flows on the interbank market. All customers and dealers observe the current payoff on foreign exchange V_t (common news) and customers receive income denominated in foreign currency $Y_{n,t}$ (private/dispersed information). The private information generates hedging motives for customer orders. Dealers enter the market with holdings of foreign currency and wealth (the sum of domestic and foreign currency holdings). We divide one trading day into three rounds. Round I: Dealers quote prices and receive orders from customers (the retail market). Round II: Dealers trade among themselves and with the broker to share inventory risk. Round III: The retail market reopens and all three market participants trade simultaneously in order to share inventory risk more broadly. The model is illustrated in the graph below.



Round I: All customers and dealers observe the current payoff on foreign exchange V_t (common news) and customers receive income denominated in foreign currency $Y_{n,t}$ (private/dispersed information). The private information generates hedging motives for customer orders. Dealers enter the market with holdings of foreign currency and wealth (the sum of domestic and foreign currency holdings). Each dealer independently and simultaneously quotes a scalar price to his/her customers, $S^I_{d,t}$ at which the dealer will buy or sell currency. Dealers quote the same price, $S^I_{d,t} = S^I_t$, in round I. The price is publicly observed by all dealers and investors and are good for orders of any size based on information available from the previous day and the new public information transmitted through the current payoff from foreign exchange holdings. Investors place their orders. Customer orders are only observed by the dealer implying that total demand is unobserved. Customer orders received by a dealer is denoted $Z^I_{d,t}$ and is positive for net customer purchases and negative for net customer sales. Public information arrives at the start of each trading day and are immediately incorporated into the quotes in round I. Private information cannot affect the quotes. Investors place their orders based on their own income. Each dealer receives a fraction of the aggregate customer orders (a noisy signal about the aggregate component of customer income).

Round II: Dealers and brokers simultaneously and independently quote a price, $S^{II}_{d,t} = S^{II}_{B,t} = S^{II}_t$. Dealers act on the information they received through customer orders in Round I, the trades each dealer initiates depends on the customer order received in Round I. Dealers trade among themselves and with the broker. FX orders made by the dealer are denoted $T^{II}_{d,t}$ and orders received by the dealer are denoted $Z^{II}_{d,t}$. Orders received by the broker are denoted $Z^{II}_{B,t}$. Each dealer has some information about the aggregate income at the start of Round II but the information is imprecise. Dealers quote the same price (based on public information) implying that the spot exchange rate must the same in Rounds I and II. Information aggregation takes place via interdealer trades in Round II. Interdealer order flows convey information on aggregate income that becomes common information to dealers towards the end of Round II. At the end of Round II, the dealers and the broker observe the aggregate interdealer order flow $X_t = \sum_{d=1}^{D} T^{II}_{d,t}$.

Round III: The retail market reopens. The broker and the dealers simultaneously and independently quote new prices $S^{III}_{d,t} = S^{III}_{B,t}$, different from the quotes in Round I and II. FX orders made by customers are denoted $T^{III}_{n,t}$, FX orders made by dealers are denoted $T^{III}_{d,t}$ and customer orders received by dealers are denoted $Z^{III}_{d,t}$. Orders received by the broker are denoted $Z^{III}_{B,t}$. Dealers also trade on the interbank market $T^{III}_{d,t}$. Dealers have learned about the aggregate interdealer order flows from Round II, this order flow is incorporated into the price quoted at the start of Round III. The unexpected aggregate order flow determines the quotes. Dealers share overnight risk with customers and the broker. Customers willingly absorbs all dealer inventory

imbalances so that all dealers and the broker's foreign exchange holdings overnight are zero.

Summary: The order flow between customers and dealers in Round I incorporates new information. Customers are assumed to have this information and then it is transmitted to dealers through order flows. Dealers learn about how customers value currencies through their willingness to sell or buy currencies at quoted prices. Dealers cannot explore this information as it is not publicly known, i.e., known by other dealers. In the model, interdealer order flows in Round II convey new information which will be used when quoting prices in Round III. Dealers do not want to hold foreign exchange overnight, overnight risk can be more efficiently shared by investors. The quotes in Round III must then be such that investors would like to hold the entire existing stock of foreign exchange. Customer income is the only source of price changes. Dealers can infer from customer income what aggregate overnight foreign exchange position that investors must be induced to hold. Interdealer order flows convey information about the shift in the portfolios of investors needed to achieve efficient risk–sharing (this is the portfolio shift).

(d) Summarize the empirical evidence on the Portfolio Shift Model.

Answer: There is a strong positive contemporaneous correlation between daily changes in the price of FX and interdealer order flow. The correlation is robust to different forms of interdealer trading and appears across a wide cross-section of currencies. The contribution of interdealer order flows to daily changes in exchange rates is much higher than that found for any other macroeconomic or financial variables. The impact of order flows on exchange rates may depend on trading volume. The contemporaneous relationship between spot rate changes and order flow applies to both interdealer flows and customer flows. Customer flows disaggregated by customer type have more explanatory power for exchange rate returns than the aggregate flows received by individual banks. Disaggregated flows can account for less of the variation in exchange rate returns than aggregate interdealer order flows, but the explanatory power of customer and dealers flows are comparable at lower frequencies.