University of Copenhagen
Department of Economics
Michael Bergman

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

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1. This question covers central bank intervention and is related to the learning objectives: describe the channels by which central bank intervention can affect the exchange rate and summarize the empirical evidence on these channels; describe and use the portfolio balance and the signaling models to analyze the effects of policy interventions (central bank interventions, monetary and fiscal policy) on the exchange rate.

   (a) Central bank intervention in practice: Assume that there is upward pressure on the domestic currency, i.e., an appreciation. The central bank must in this situation defend the value of the currency and therefore buys one unit of foreign bonds from a foreign commercial bank. The transaction is carried out by a domestic commercial bank. The holdings of domestic bonds in the foreign commercial bank decreases but at the same time the bank receives payment and there is therefore an increase in deposits that the foreign bank holds in a domestic commercial bank. The total effect is that both assets and liabilities held at the domestic bank increase and as a result, there is an increase in monetary base since holdings of foreign reserves increase.

   The operation described above is called a non-sterilized foreign exchange operation, the money stock increased. This operation can be combined with an open market operation such that there is no change in the money stock, the change in the money stock is sterilized. Following the example above, the central bank should sell domestic bonds to domestic households. This reduces the money stock (domestic households deposits at the domestic commercial bank decreases) and their holdings of domestic bonds increase. The total effect is that the money stock is unchanged but the composition of the portfolios have changed, the public holds fewer foreign bonds and more domestic bonds. This is an example of a sterilized central bank operation.

   (b) There are in principle three main arguments for central bank interventions: (a) "wrong rate" argument; (b) 'exchange rate overshooting" argument; and (c) "adjustment argument".

   "The wrong–rate argument": Under floating exchange rates, the exchange rate is determined in an inefficient market that tends to generate the wrong rate instead

of the correct rate. The monetary authority can choose an exchange rate in line with economic fundamentals. The monetary authorities might be able to produce a more appropriate exchange rate. The rate viewed by the monetary authority is the correct rate. Speculation can be destabilizing producing large changes in exchange rates that could have negative impact on the economy, for example by reducing trade. It could be the case that the market is using the wrong model, has wrong expectations, cannot interpret or extract relevant information from news and so on. Intervention should, therefore, be used if agents on the market extract misleading information from news. This conclusion is based on the presumption that the monetary authority has superior information. Intervention is used to send relevant and correct information to the market.

"Exchange rate overshooting argument": Intervention mitigates the costs of exchange rate overshooting. If the Dornbusch overshooting model is correct, we know that monetary policy can lead to short–run real exchange rates that overshoot the long–run equilibrium real exchange rate. For example, expansionary monetary policy can lead to an undervalued currency which can then have unwanted effects on the economy. These misalignments distort for example the allocation of resources between tradable and non–tradable sectors as well as the consumption patterns between the two. The undervalued currency tends to raise the domestic price level, placing a downward pressure on real wages. These costs and the extent of overshooting can be reduced by intervention.

"Adjustment argument": Intervention is an instrument for smoothing necessary economic adjustments. If a country has a persistent balance–of–payments surplus because the traded goods sector is too large relative to the non–traded goods sector, the currency will tend to appreciate. As a result, capital and labor move from the traded goods sector to the non–traded goods sector. During this adjustment, unemployment will rise. To moderate the appreciation of the exchange rate, the monetary authority can intervene in order to allow time for the traded goods sector to contract and the non–traded goods sector to expand. Intervention can reduce the costs of adjustments.

"Secret intervention": A secret intervention can be defined as foreign exchange operations that are not disclosed to the market participants (at least not contemporaneously). 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. The Fed and Bundesbank (ECB) and other central banks have adopted more transparent policies but Bank of Japan still relies on secret interventions. What is important is that if interventions are secret, then there is no signal to the market that could change market expectations, the signaling channel breaks down.

The main arguments for conducting secret interventions are: (a) To minimize

the effects of an unwanted intervention operation (decision made by Treasury Department but Fed carries out intervention); (b) the perceived risk and volatility in the FX market (risky to intervene when uncertainty is high and if reputation is not very strong); and (c) portfolio adjustment arguments. Only the second argument is plausible according to the literature. It is very risky to intervene in a turbulent market and the signals may be misinterpreted by market participants leading to increased volatility and uncertainty. Therefore, it makes sense for the central bank to intervene secretly. Furthermore, this implies that central bankers disregards the signaling channel and relies on the portfolio channel. But this implication contradicts empirical evidence suggesting that most central banks rely on the signaling channel, not the portfolio balance channel and they also regard consistency of policies and reputation as important.

(c) The portfolio balance channel: This approach is based on the portfolio balance model discussed in the curriculum. Official sterilized intervention is carried out as a foreign exchange operation where the effects on the monetary base is sterilized by an open market operation. There is a swap of foreign bonds for domestic bonds (or the opposite) in the portfolios held by the central bank and the households and both the exchange rate and the interest rate adjusts to the portfolio adjustments. The main assumption in these models is that domestic and foreign bonds are imperfect substitutes, they are not equally risky implying that there is a risk premium in the uncovered interest rate parity condition. Therefore, the portfolios held by domestic households adjusts to changes in risk perceptions. If domestic and foreign bonds are perfect substitutes, then the portfolio balance model collapses to the standard monetary model and non-sterilized foreign exchange interventions can have no effect on the exchange rate or the interest rate.

The signaling channel: Official intervention serves as a signal of future monetary policy by providing the foreign exchange market with new relevant information. It is assumed that the current exchange rate is a function of current and discounted expected future fundamentals, a relationship consistent with almost all exchange rate models. An intervention on the FX market sends a signal to the market participants about future fundamentals. If future fundamentals change, the current exchange rate will also change. Sterilized interventions affect expectations about future movements in the relative money supply, income and interest rates with a feedback effect on the exchange rate. This effect also occurs in the monetary models, when foreign and domestic bonds are perfect substitutes. An underlying assumption is that the monetary authority has superior information and that they can reveal this information to the market by intervening on the foreign exchange market.

(d)
- Hutchison and Fatum conduct an event study focusing on the direction of exchange rate movements on days (and windows) following an official inter-

vention. They find that interventions affect exchange rates in the shortâĂŞrun and there are larger effects when intervention is combined with interest rate changes. The authors argue that this evidence is consistent with the assumption that interventions signal monetary policy.

- Dominguez and Frankel use an alternative approach and perform tests of the signaling channels without assuming rational expectations of exchange rates. Instead they use survey data on dollar-mark exchange rate expectations. The empirical evidence suggest that reported intervention significantly affect exchange rate expectations and that the effectiveness of intervention is enhanced if it is publicly announced. Overall, Dominguez and Frankel provide strong statistical evidence that sterilized intervention is effective through the signaling channel.
- Other papers often find that the signaling channel cannot be rejected but results are dependent on sample periods, methods and data.
- Another approach used in the literature is to test whether central bank interventions signal future changes in monetary policy. Lewis uses publicly available data on US foreign exchange rate intervention for the period from 1985 through 1990 and examines the relationship between foreign exchange market intervention and monetary policy, testing the hypothesis that official interventions signal changes in future monetary policy. Lewis' study suggests that official intervention may predict monetary policy variables and vice versa. More recently, Kaminsky and Lewis examine the prediction of signaling channel theory that central banks signal a more contractionary monetary policy in the future by buying domestic currency today and, therefore, that expectations of future tighter monetary policy make the domestic currency appreciate, even though the current monetary effects of the intervention are typically offset by sterilization. Kaminsky and Lewis then argue that this expectation presumes that central banks support interventions with subsequent changes in monetary policy. Their empirical results support this assumption. Another contribution is a paper by Bonser-Neal, Roley and Sellon who re-examine the relationship between the Federal Reserve monetary policy actions, US interventions in currency markets and exchange rates using the Federal funds rate. The authors find that the exchange rate generally responds immediately to US monetary policy actions and that this response is usually consistent with the overshooting hypothesis. The authors also find evidence of signaling and leaning against the wind in US intervention policies over the sample period.
- The overall conclusion from the empirical literature is that the evidence on the effectiveness of official intervention, through the signaling channel is still mixed. However, the recent literature does suggest a significant effect of official intervention on both the level and the change of exchange rates and

there is more empirical support for the signaling channel than the portfolio balance channel.

2. This question relates to the learning objectives: describe and use microstructure based models (rational expectations and portfolio shift models) to analyze price determination on the foreign exchange market and summarize the empirical evidence on these models.

   The model used in the question combines microstructure and macro perspectives to allow for an analysis of the differences between standard macro-based exchange rate models and a micro-based macro model. The purpose of this model is to derive an exchange rate equation that incorporates one of the main ideas in the micro structure literature, that order flows provide an additional source of variation in the exchange rate and that the trading (and differences in information available for dealers and investors when forming expectations) affects the price of foreign exchange. The model use in the problem is discussed in the curriculum.

   (a) There are 2 two countries populated by a continuum of risk-averse agents, indexed by $n \in [0, 1]$; and D risk-averse dealers who act as market makers in the spot market for foreign currency. The log spot price quoted by all dealers at the start of week t is

   $$s_t = \mathbb{E}_t^D s_{t+1} + \hat{r}_t - r_t - \delta_t, \tag{1}$$

   where expectations are conditioned on dealers' common information Ω_t^D which includes domestic and foreign interest rates. δ_t is the risk premium (which is a function of dealers' common information Ω_t^D). Note that this is UIP plus a risk premium. The equation implies that the price quoted by all dealers at the start of week t is equal to the payoff from holding foreign currency until next week $\mathbb{E}_t^D s_{t+1} + \hat{r}_t - r_t$ less a risk premium δ_t. The risk premium is determined by the requirements of efficient risk sharing, dealers will choose δ_t such that their holdings of risky currencies at the end of the week t is zero. All dealers are located in the US (home country). They therefore choose the risk premium, δ_t, such that their expected holdings of euros (the euro zone is the foreign country) at the end of week t equal zero.

   The only other actors in the model are the FED and ECB, who conduct monetary policy by setting short-term nominal interest rates (conditional on inflation, output and real exchange rates). Dealers' interest rate expectations incorporate a view on how central banks react to changes in the macro economy.

   $$\mathbb{E}_t^D(\hat{r}_{t+i} - r_{t+i}) = (1+\gamma_\pi)\mathbb{E}_t^D(\Delta\hat{p}_{t+1+i} - \Delta p_{t+1+i}) + \gamma_y \mathbb{E}_t^D(\hat{y}_{t+i} - y_{t+i}) - \gamma_\varepsilon \mathbb{E}_t^D \varepsilon_{t+i} \tag{2}$$

   where we have assumed that the expected interest rate differential depends on

   - the future expected inflation differential $\mathbb{E}_t^D(\Delta\hat{p}_{t+1+i} - \Delta p_{t+1+i})$,

- the future difference between output gaps $\mathbb{E}_t^D(\hat{y}_{t+i} - y_{t+i})$, and
- the real exchange rate $\mathbb{E}_t^D \varepsilon_t \equiv s_t + \hat{p}_t - p_t$.

The third equation simply defines the real exchange rate

$$\varepsilon_t = s_t + \hat{p}_t - p_t \tag{3}$$

where $\hat{p}$ is the foreign (euro) price level and p is the home (US) price level.

(b) To derive the expression

$$s_t = (\hat{r}_t - r_t) + \mathbb{E}_t^D \sum_{i=1}^{\infty} \rho^i f_{t+i} - \mathbb{E}_t^D \sum_{i=0}^{\infty} \rho^i \delta_{t+i} \tag{4}$$

where

$$f_t = (1 + \gamma_\pi)(\Delta\hat{p}_{t+1} - \Delta p_{t+1}) + \gamma_y (\hat{y}_t - y_t) + \tfrac{1-\rho}{\rho}(p_t - \hat{p}_t) \tag{5}$$

we first rewrite the UIP relation as

$$\mathbb{E}_t^D s_{t+1} = \mathbb{E}_t^D[\hat{r}_t - r_t - \delta_t] + \mathbb{E}_t^D s_{t+2}$$

We have an assumption about how dealers think the central bank responds to changes in the macro economy (the second equation above). Insert this into the UIP relation such that

$$\mathbb{E}_t^D s_{t+1} = \mathbb{E}_t^D[(1+\gamma_\pi)\mathbb{E}_t^D(\Delta\hat{p}_{t+1+i} - \Delta p_{t+1+i}) + \gamma_y \mathbb{E}_t^D(\hat{y}_{t+i} - y_{t+i}) - \gamma_\varepsilon \mathbb{E}_t^D \varepsilon_{t+i} - \delta_t] + \mathbb{E}_t^D s_{t+2}$$

and then we use the definition of the real exchange rate such that

$$(1 + \gamma_\varepsilon)\mathbb{E}_t^D s_{t+1} = \mathbb{E}_t^D[f_{t+1} - \delta_{t+1}] + \mathbb{E}_t^D s_{t+2}$$

where

$$f_{t+1} = (1 + \gamma_\pi)(\Delta\hat{p}_{t+1} - \Delta p_{t+1}) + \gamma_y(\hat{y}_t - y_t) + \gamma_\varepsilon(p_t - \hat{p}_t)$$

Let

$$\rho = \frac{1}{1 + \gamma_\varepsilon}$$

then we have that

$$\mathbb{E}_t^D s_{t+1} = \rho \mathbb{E}_t^D f_{t+1} + \rho \mathbb{E}_t^D s_{t+2}$$

Solve this difference equation under the assumption of no bubbles. Iterate forward to obtain

$$\mathbb{E}_t^D s_{t+1} = \mathbb{E}_t^D \sum_{i=1}^{\infty} \rho^i (f_{t+i} - \delta_{t+i}) + \mathbb{E}_t^D \lim_{i \to \infty} \rho^i s_{t+i}$$

and if we impose the assumptions of no bubbles we have

$$\mathbb{E}_t^D s_{t+1} = \mathbb{E}_t^D \sum_{i=1}^{\infty} \rho^i (f_{t+i} - \delta_{t+i})$$

Finally, combining this with the UIP relation we find that

$$s_t = (\hat{r}_t - r_t) + \mathbb{E}_t^D \sum_{i=1}^{\infty} \rho^i f_{t+i} - \mathbb{E}_t^D \sum_{i=0}^{\infty} \rho^i \delta_{t+i}$$

which is the relation in the problem.

(c) Take the expectation of the demand for euros and impose the risk sharing condition, we then have

$$\mathbb{E}_t^D \alpha_t = \mathbb{E}_t^D(\alpha_s(\bar{\mathbb{E}}_t^n s_{t+1} - s_t + \hat{p}_t - r_t) + h_t) = 0$$

Using UIP including the risk premium and the hint we can rewrite $\alpha_s(\bar{\mathbb{E}}_t^n s_{t+1} - s_t + \hat{p}_t - r_t)$ as $\alpha_s \delta_t - \alpha_s s_{t+1}^e$ where $s_t^e = \bar{\mathbb{E}}_t^n s_{t+1} - s_{t+1}$. This implies that

$$\mathbb{E}_t^D \alpha_t = \mathbb{E}_t^D(\alpha_s \delta_t - \alpha_s s_{t+1}^e + h_t) = 0$$

and then we finally find that the risk premium is given by

$$\delta_t = \mathbb{E}_t^D \left[s_{t+1}^e - \tfrac{1}{\alpha_s} h_t \right]$$

(d) Combine equations (4) and (7) such that

$$s_t = (\hat{r}_t - r_t) + \mathbb{E}_t^D \sum_{i=1}^{\infty} \rho^i f_{t+i} + \tfrac{1}{\alpha_s} \mathbb{E}_t^D \sum_{i=0}^{\infty} \rho^i h_{t+i} - \tfrac{1}{\rho} \mathbb{E}_t^D \sum_{i=1}^{\infty} \rho^i s_{t+i}^e$$

(e)
- This equation identifies the foreign currency price all dealers quote, s_t is a function of information available to dealers Ω_t^D, at the time they quote prices. This information set includes contemporaneous interest rates in both countries but not other contemporaneous fundamentals that comprise the current state of the economy.
- It includes a risk premium that incorporates dealers' estimates of aggregate hedging demand and agents' forecast errors.
- These factors can be a source of variation in the spot rate if dealers view the current and future monetary policy unchanged.
- Standard models suggest that spot rates depend on current and expected future fundamentals but in the model above, dealers expectation of the agents' average forecast errors affect the spot rate via their implication for risk-sharing.

(f) Consider the risk premium equation derived in (c). This equation implies that the risk premium depends on (i) aggregate hedging demand $\mathbb{E}_t^D h_t$, and (ii) the average error agents make when forecasting next week's spot rate s_{t+1}^e. Dealers lower the

risk premium when they anticipate a rise in the aggregate hedging demand for euros, the implied fall in the excess return agents expect offset their desire to accumulate larger euro holdings. Dealers lower the risk premium to offset agents' desire to accumulate larger euro holdings when they are viewed as too optimistic about the future spot rate, i.e., when $\mathbb{E}_t^D s_{t+1} < \mathbb{E}_t^D \overline{\mathbb{E}}_t^n s_{t+1}$. Order flows convey information on agents' hedging demands providing a direct link from order flows to the risk premium and onwards to quotes. Note that order flows send dispersed information to the dealers, information that only customers have access to at the time of trade. Order flows send information about the current and future states of the macroeconomy, information that dealers use when revising the quotes.

(g) Empirical evidence strongly supports the presence of the link between the macro economy, order flow, and high frequency exchange rate returns. Between 20 and 30 percent of the variance in monthly excess returns in the USD/EUR can be linked back to developments in the macroeconomy. These transaction flows also have significant incremental forecasting power for GDP growth, money growth, and inflation in both the US and Germany over horizons of one to two quarters. Micro-based models point to the role of order flow as a carrier of macroeconomic information. This information appears useful in revising forecasts of future changes in macro fundamentals, the channel emphasized by macro models. It also appears useful in revising dealer's estimates of current macroeconomic conditions.