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Modeling and Market
Making in Foreign Exchange
IEOR E4722
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Lecture 1 (Spot Markets) Assignment

Due start of class, Wednesday May 31, 2017

Question 1 (2 marks)

Describe the four factors that contribute to the bid and ask prices a market maker will show to a client during voice trading?

- Inter-dealer market, market where a dealer can diffuse his risk. The differential between the prices of the inter-dealer market and the prices offered by the dealer impact on his ability to hedge or diffuse his risk.
- Current risk position, holding a long (short) position leads him to move towards lower (higher) prices
- Market views, a clear indication of the direction of the market might induce the dealer to take risk accordingly
- Client behavior, mainly if the client is usually right about the direction of the market

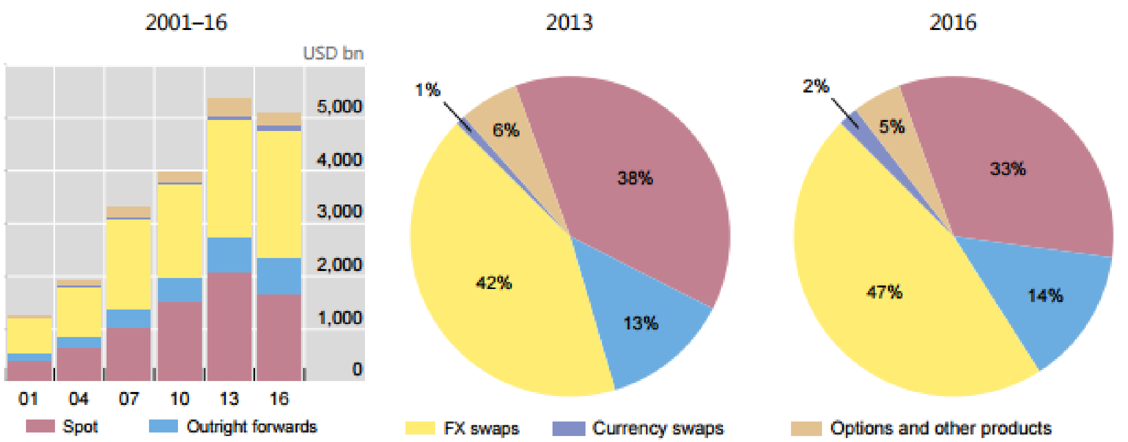
Question 2 (2 marks).
Why has the daily turnover in the FX markets increased so much in the past fifteen years? Give some statistics.

The FX market transitioned from closing trades by phone to closing trades electronically. The use of electronic resources allowed the commoditization of the trades, and also allowed to accurately quantify the performance of trades over time, leading to an increase of competitiveness between dealers which force them to reduce bid/ask spreads, which reduced the entry barrier for participants seeking trade over the FX market with a smaller time frame. Shorter time frames reduced the perception of risk, which lead to an increase in volume of capital by trade. In short, the introduction of electronic resources moved the FX Spot Market from $386 billion to $2.0 trillion daily between April'01 to April'13, a 530% increase.

It is noteworthy to mention that the FX Spot Market declined a 19% from $2.0 to $1.7 trillion daily between April'13 and April'16. This reduction was driven by an increase in bank trading regulatory restrictions due to a global market rigging scandal. Interestingly enough, this reduction in the Spot Market coincides with a 6% increase in FX Swaps to $2.4 trillion per day in April'16.

Foreign exchange market turnover by instrument

Net-net basis,[1] daily averages in April | Graph 2



[1] Adjusted for local and cross-border inter-dealer double-counting.

(Source: BIS Triennial Central Bank Survey)

Question 3 (4 marks)

Describe the OTC market structure and the different roles involved in executing a trade. Describe the steps involved in executing a trade for voice trading and then for electronic trading.

OTC Market Structure

- Clients, the ones that need the service that the OTC market provide.
- Salesperson, they act as intermediaries between clients and traders. Their role is engage with clients at an -optimistic- emotional level. But also act as a barrier between clients and traders, avoiding the risk of having clients attempting a negotiation.
- Traders, the ones who quantify the bid/ask prices accordingly to the risk position and volume of the trade. If the trade offered to the client is closed, they hedge the risk through the inter-dealer market.

Steps for voice trading

1. Clients contact dealers asking for bid/ask prices
2. Salesperson informs the trader who the client is and asks for a bid/ask pricing valuation
3. Trader looks at the spread of the inter-dealer market, considers his current risk position as well as historical trading behavior of the client to set a bid/ask price
4. Salesperson quotes the bid/ask price back to the client

Steps for electronic trading

The steps through electronic trading mirror the voice trading. However the salesperson disappear and the bid/ask price is provided by the system. The traders oversee the risk accumulated by the system, and intervene if considered necessary.

Question 4 (4 marks)

Today is October 27th, 2015. Tomorrow (October 28th) is a good business day for all three currencies. October 29th is a JPY currency settlement holiday. October 30th (a Friday) is a USD settlement holiday and November 2nd (a Monday) is a EUR settlement holiday. November 3rd is a good business day for all three currencies.

The EURUSD mid-market spot rate is 1.1300 (the price of a EUR in USD) and the USDJPY mid-market spot rate is 120.00 (the price of a USD in JPY). The USD interest rate is 0.25%, the EUR interest rate is 0.50%, and the JPY interest rate is 0.10%.

What are the spot dates for EURUSD, for USDJPY, and for EURJPY? What is the EURJPY mid-market spot rate implied from the triangle arbitrage?

date	EUR	USD	JPY		EURUSD	EURJPY	USDJPY
10/27/2015					T=0	T=0	T=0
10/28/2015					1	1	1
10/29/2015			holiday		2	-	-
10/30/2015		holiday			-	-	-
10/31/2015		weekend			-	-	-
11/1/2015		weekend			-	-	-
11/2/2015	holiday				-	-	2
11/3/2015					3	2	3
					T, time to settlement		

Assuming 2 settlement days, spot dates are,

- for EURUSD, Oct 29, 2016
- for EURJPY, Nov 3, 2016
- for USDJPY, Nov 2, 2016

To calculate the Spot Rate at settlement of the EURJPY it is needed to depreciate the Spot rates of the other 2 pairs, counting the calendar days from their respective settlement date to the EURJPY settlement date. And then apply the triangle arbitrage:

- Spot rate for EURUSD at EURJPY settlement date,
$$F_{EU} = S_{EU}\, e^{(Q-R)T} = 1.13\, e^{(0.25\%-0.5\%)\cdot 1/365} = 1.129961$$
- Spot rate for USDJPY at EURJPY settlement date,
$$F_{UJ} = S_{UJ}\, e^{(Q-R)T} = 120.0\, e^{(0.1\%-0.25\%)\cdot 5/365} = 119.9995$$
- Triangle arbitrage,
$$\frac{1\, EUR}{1.129961\, USD} \cdot \frac{1\, USD}{119.9995 JPY} = \frac{1\, EUR}{135.5948\, JPY} => 135.5948\, EURJPY$$

Question 5 (2 marks)

Same market as Question 4. Assume zero bid/ask spread in interest rates.

Take the bid/ask for EURUSD as 1.1299/1.1301, and the bid/ask for USDJPY as 119.99/120.01. What is the bid/ask for EURJPY implied from the triangle arbitrage?

- EURJPY Bid,
$$B_{EJ} = 1.1299\, e^{(0.25\%-0.5\%)\cdot 5/365} \cdot 119.99 \cdot e^{(0.1\%-0.25\%)\cdot 1/365} = 135.5715$$
- EURJPY Ask,
$$A_{EJ} = 1.1301\, e^{(0.25\%-0.5\%)\cdot 5/365} \cdot 120.01 \cdot\ e^{(0.1\%-0.25\%)\cdot 1/365} = 135.6181$$

Question 6 (10 marks)

In Python, implement a variation of the "toy simulation algorithm" we discussed in class. Model parameters to assume:

- Spot starts at 1
- Volatility is 10%/year
- Poisson frequency ⍰ for client trade arrival is 1 trade/second
- Each client trade that happens delivers a position of either +1 unit of the asset or -1 unit of the asset, with even odds
- Bid/ask spread for client trades is 1bp
    - Receive PNL equal to 1bp*spot*50% on each client trade (since client trades always have unit notional in this simulation)
- Bid/ask spread for inter-dealer hedge trades is 2bp
    - Pay PNL equal to 2bp*spot*hedge notional*50% on each hedge trade
- A delta limit of 3 units before the algorithm executes a hedge in the inter-dealer market.

Use a time step ⍰t equal to 0.1/⍰ and assume that only a single client trade can happen in each time step (with probability equal to $1 - e^{-\lambda\,\Delta t}$). Use 500 time steps and a number of simulation runs to give sufficient convergence.

When converted between seconds and years, assume 260 (trading) days per year.

The variation in the algorithm: when the algorithm decides to hedge, it can do a partial hedge, where it trades such that the net risk is equal to the delta limit (either positive or negative depending on whether the original position was above the delta limit or below -1*delta limit); or it can do a full hedge, like in the algorithm we discussed in class, where the net risk is reduced to zero.

Use the Sharpe ratio of the simulation PNL distribution to determine which of those two hedging approaches is better.

Your solution should deliver the Python script that implements the simulation, and you should explain your answer by giving numerical results from the simulation as well as some qualitative intuition behind the result. Include data that shows that you have used sufficient Monte Carlo simulation runs to show that your final result is not affected by statistical noise.

Marks will be given for both the numerical results generated from the simulation as well as the quality of your Python code. Remember to include lots of explanatory comments in your code and use variable names that are meaningful. Use external packages like numpy/scipy where applicable rather than rolling your own low-level numerical functions like random number generators. For top marks, use only vectorized operations across the Monte Carlo paths to speed up execution.

I solved this question in MATLAB, as I am more familiar with, thinking on transfer the code to Python once completed, but I didn't have time to do so. I will do better in the next assignment. The numerical results I obtained are,

- Full Hedge
    - Sharpe ratio: 1.490
    - PNL Mean: 0.00084
    - PNL Std Dev: 0.00056

- Partial Hedge
    - Sharpe ratio: 3.332
    - PNL Mean: 0.00176
    - PNL Std Dev: 0.00053

As is right now 5:52pm. Second approach is better because, in short, risk is rewarded.

```
function HW1()
    clear;clc;
    vol=0.1*sqrt(1/260);
    lmbd=60*60*24;dlt_t=0.1/lmbd;
    trdng_prob=1-exp(-lmbd*dlt_t);
    sprd_clnt=1e-4;
    sprd_dlr=2e-4;
    dlt_lmt=3;
    n_stps=500;
    n_rns=1e6;
    run_sim(vol,sprd_clnt,sprd_dlr,dlt_lmt,dlt_t,n_stps,n_rns,trdng_prob,0);
    run_sim(vol,sprd_clnt,sprd_dlr,dlt_lmt,dlt_t,n_stps,n_rns,trdng_prob,1);
end
function rr=run_sim(vol,sprd_clnt,sprd_dlr,dlt_lmt,dlt_t,n_stps,n_rns,trdng_prob,hdg_type)
    tic
    pnls=NaN*ones(1,n_rns);
    trades=NaN*ones(1,n_rns);
    hedges=NaN*ones(1,n_rns);
    for this_run=1:n_rns
       hdg_bool=zeros(n_stps,1);
       trd_bool=zeros(n_stps,1);
       nrml_rnd=random('Normal',0,sqrt(dlt_t),[n_stps,1]);
       trd_rnd=random('Uniform',0,1,[n_stps,1]);
       pos_rnd=random('Binomial',1,0.5,[n_stps,1]); pos_rnd(pos_rnd==0)=-1;
       trd_bool(trd_rnd<trdng_prob)=1;
       pos_rnd(~trd_bool)=0;
       postn=cumsum(pos_rnd);
       hdg_wht=[];
       while ~isempty(cond_hedge(postn,dlt_lmt,hdg_type))
           hdg_this=cond_hedge(postn,dlt_lmt,hdg_type);
           hdg_bool(hdg_this)=1;
           sgn=postn(hdg_this)/abs(postn(hdg_this));
           hdg_wht=[hdg_wht postn(hdg_this)];
           postn(hdg_this:end)=cumsum([sgn*dlt_lmt*hdg_type;pos_rnd(hdg_this+1:end)]);
       end
       sgn=(postn+eps)./abs(postn+eps);
       postn(hdg_bool==1)=hdg_wht;
       hdg_ntnl=hdg_type*sgn.*postn+((-1)^hdg_type)*dlt_lmt;
       pnl_hdges=-hdg_bool.*hdg_ntnl.*sprd_dlr.*0.5.*cumprod(1+vol*nrml_rnd(:));
       pnl_trdes=trd_bool.*sprd_clnt*0.5.*cumprod(1+vol*nrml_rnd(:));
       pnl_iters=postn.*vol.*cumprod(1+vol*nrml_rnd(:)).*nrml_rnd;
       pnl=cumsum(pnl_hdges+pnl_trdes+pnl_iters);
       pnls(this_run)=pnl(end);
       trades(this_run)=sum(trd_bool);
       hedges(this_run)=sum(hdg_bool);
    end
    rr.nruns=n_rns;
    rr.sharpe=mean(pnls)/std(pnls);
    rr.mean_pnls=mean(pnls);
    rr.std_pnls=std(pnls);
    rr.mean_trades=mean(trades);
    rr.mean_hedges=mean(hedges);
    toc;rr
end
function hedge_this=cond_hedge(postn,dlt_lmt,hdg_type)
    if hdg_type==0
        hedge_this=find(abs(postn)==dlt_lmt,1);
    elseif hdg_type==1
        hedge_this=find(abs(postn)>dlt_lmt,1);
    else
        disp();
    end
end
```

```
res =

  struct with fields:

         nruns: 1000000
        sharpe: 1.48353190459797
     mean_pnls: 0.000836852744623321
      std_pnls: 0.000564094875229597
   mean_trades: 47.564971
   mean_hedges: 5.13838

Elapsed time is 236.821871 seconds.

res =

  struct with fields:

         nruns: 1000000
        sharpe: 3.32756223066947
     mean_pnls: 0.00175664005763336
      std_pnls: 0.000527905997202023
   mean_trades: 47.580677
   mean_hedges: 6.225927

Elapsed time is 247.268424 seconds.
>>
```