Back-Testing Methods Used to Estimate Future Spot Exchange Rates Utilizing Bloomberg Data

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Since students ask for real life examples and employers look for better excel skills, I added an empirical project to International Finance class. Using Bloomberg data students, in teams of four, calculate annual and average annual currency appreciations, as well as, various parity conditions between dollar and major foreign currency. In the last phase of the project students back-test methods for predicting future spot exchange rates. As an incentive to experiment with different lengths of the estimation period, the team with the smallest standard deviation between estimated and actual exchange rates earn bonus points.

INTRODUCTION

One of the most frequent comments on teaching evaluation forms submitted by students in both required and elective classes is that "classes should be made more interesting by inclusion of real life examples".

I started teaching International Finance, as a doctoral student, at the University of Pittsburgh's Katz Graduate School of Business, in the Spring of 1995. My mentor at that time, Dr. Robert Nachtmann, currently the Dean of the University of Texas at El Paso's College of Business Administration, warned me that MBA students, many older than me, will eat me alive if I limit my classes to text book content alone. In addition to several hot topics of the time, which could be used to spice the lectures, Bob suggested to ask students to test if the Forward Exchange Rates are an Unbiased Predictor of the Future Spot Exchange Rates.

To prevent riots of stressed and angry MBAs fighting over limited resources, I collected the data on the indirect dollar spot and forward exchange rates for yen by hand from the hard copies of the Wall Street Journal kept in the library, and made it available to students.

Couple of years later, I dropped this crude "project" and replaced it with Kenneth Froot's "The 1994-95 Mexican Peso Crisis" from Harvard Business School Case Collection. This time I did not have to roll up my sleeves and flip through WSJ collection. Data on exchange rates between dollar and peso, as well as US and Mexican CPI indices came with the case. Suggested questions and answers regarding the peso devaluation, why it occurred, was it predictable and relationships between macroeconomic policy and capital markets, capital flows and economic growth, were also included.

I joined Robert Morris University's School of Business in 2005. Leading to our successful AACSB accreditation in 2009, and especially in preparation for the move into the new School of Business Complex, which opened in the Fall of 2011, all faculty were asked to think about ways to utilize PNC Trading Center with 32 computers and collection of professional, statistical and pedagogical software,

including Bloomberg. At the same time, members of the Advisory Board for our Department of Finance were continuously stressing the needs of employers for college graduates with better excel knowledge.

I decided to design an empirical project that will satisfy our students' desire for more real life content of the classes, the School of Business' need for better utilization of facilities, as well as employers', and hence our students', demand for graduates with excel proficiency.

For sentimental reasons, I went back to my original project. Instead of diving into hard copies of Wall Street Journal, with couple of computer commands at Bloomberg terminal, I collected quarterly data on the indirect dollar spot and forward exchange rates for yen, quarterly CPI indices in USA and Japan, and quarterly annual LIBOR rates for dollar and yen from the 4th quarter of 1991 to the 4th quarter of the calendar year preceding the semester. In addition to data, students were provided with detailed instructions on how to fulfill the assignments (see Appendix) separated into three phases. To prevent students from passing the assignments to their colleagues, the project in subsequent semesters has been changed to dollar versus British pound or dollar versus Swiss Francs analysis.

After discussing each topic in the class and working through several examples, students were assigned the homework from Alan Shapiro's textbook and tested through in-class quiz before they were shown how to apply theoretical relationship on real life data and asked to do it themselves in teams of four throughout the entire semester.

PHASE ONE OF THE PROJECT: APPRECIATIONS AND FORWARD PREMIUMS

At the beginning of the excel session students are reminded that it is important to maintain the original data in separate worksheet and do calculations in separate worksheets into which the entire or subset of provided data has been copied. Throughout the demonstrations students are shown excel features, such as autofill, which greatly increase productivity. Recommendation to be "lazy programmer" and use build in excel functions, as well as copy-and-paste and cut-and-paste in order to minimize the errors and increase the speed, is repeatedly stressed and shown to students.

Taking advantage of the PNC Trading Center benefit of each student having his/her computer, each of the five methods for computing nominal realized appreciation and forward premium, described in details in instructions for the project, was demonstrated to students highlighting their implications. Rich structure of quarterly data allows calculation of annual appreciation (change in currency value between 4th quarters of subsequent years) and average annual appreciation, which includes changes from quarter to subsequent quarter and changes between the same quarters of subsequent years. Although annual appreciation is the simples method of calculating rate of change in the value of the currency it ignores variations during the year, which are captured when annual average of quarterly changes in the value of currency are calculated. At this point the different implications of arithmetic average, as the best predictor of the future, and geometric average, as an average measure of past performance, was stressed to students.

Given that all rates (interest, inflation, currency appreciation, forward premium, return) are by law quoted as annual percentage rate, which is based on simple interest calculations, before changes in currency value between subsequent quarters can be averages they have to be annualized by simple multiplying them by 4. Since change in currency between the same quarters of the subsequent year span the entire year, no annualization is necessary before those quarterly changes are averaged.

Although it is unlikely for major currencies, students are reminded that the geometric average cannot be calculated if any quarterly change is less than -100%, because it makes the product of all quarterly changes negative and prevents taking the 4th root.

While appreciation is longitudinal analysis of realized spot rates at different points in time, the forward premium is the latitudinal analysis of spot and forward rates observed at the same point in time. The implication of this difference in the nature of these two rates of change is that neither arithmetic nor geometric average of changes between the same quarters of the subsequent years can be used for forward premiums. The only methods that can be used are the annual forward premium based on spot and forward rated observed in the 4th quarter of each year, as well as arithmetic and geometric mean of forward premiums calculated in each of the four quarters of a given year.

After they have been shown how to calculate appreciation and forward premium for dollar, which for indirect dollar quote for yen is defined as the end of the period price over the beginning of the period price minus one, students are asked how to compute the same measure for yen. Without exception, the answer, usually from good students, is to just flip formula to beginning of the period price over the end of the period price minus one. The "Eureka moment" on students' faces, when they realized how much easier and faster is to convert the indirect dollar quotes for yen into the direct dollar quotes for yen and just copy the same formulas that have been used for dollar calculations to compute yen measures, is priceless.

PHASE TWO OF THE PROJECT: PARITY CONDITIONS

Approximately a month later, following the discussion of parity conditions in the class, the second excel session is used to related theoretical ties between different monetary variables.

Calculations of annual inflation and annual arithmetic or geometric average of quarterly inflations is analogous to computations of appreciation and is based on the same five methods. Once inflation rates for both countries are calculated, end of period real exchange rate, as well as real realized appreciation can be computed. In this assignment it is crucial to stress the need to use the inflation rate appropriate for the particular method of real appreciation calculation. In other words, for annual real realized appreciation we have to use annual inflation and quarterly real realized appreciation requires the use of quarterly inflations.

Relative purchasing power parity (RPPP) implied appreciation for particular currency is defined as one plus inflation of accompanying currency divided by one plus inflation of currency that is being analyzed minus one. It can be calculated as annual RPPP implied appreciation using annual inflation rates or annual arithmetic and geometric average of quarterly RPPP implied appreciations using inflation from subsequent quarters or inflation from same quarters of subsequent years.

International Fisher's Effect (IFE) implied appreciation for given currency is computed as one plus nominal interest rate for companion currency divided by one plus nominal interest rate for currency that is being analyzed minus one. It can be calculated as annual IFE implied appreciation based on annual nominal interest rates or annual arithmetic and geometric men of quarterly IFE implied appreciation based on nominal interest rates in subsequent quarters. Since nominal interest rates are levels and not rates of change, methods based on change between the same quarters of subsequent years cannot be used for IFE implied appreciation. Instead of US and Japanese treasury rates nominal interest rates were proxied by LIBOR for consistency and data availability reasons.

Testing if current forward exchange rate is an unbiased predictor of the future spot exchange rate can be accomplished by using residual and regression method and visualized by plotting both current spot and past forward rates on the same graph. The first step is to stagger the data so that current spot rate is compared versus 90, 180 and 360 day forward rates from one, two and four quarters ago. Residual method is based on the definition of the unbiased predictor and tests whether the arithmetic average of the difference between the current spot and forward rate from N days ago is zero over long enough time period (Johnson and Wichern, 2007). Regression method of regressing past forward rates, as an independent variable, on current spot rates, as a dependent variable, tests whether Y intercept and slope coefficient equal zero and one, respectively. Since residual from the regression analysis is based on the difference between the actual spot rate and the estimated spot rate computed from actual forward rates and estimated regression coefficients, it cannot be used for residual method of testing which is based on actual spot and actual forward rates.

Interest rate parity stipulates that return on $1 invested in the USA has to equal the return on $1 converted into yen using spot rate, invested in Japan and converted back into dollar using forward rate. Following this definition, the test for Covered Interest Arbitrage based on indirect dollar quote for yen is: $1 + I^{\$}_{360/N} = S(1 + I^{¥}_{360/N})/F^{N}$, where N is 90, 180 or 360 days forward. For each of 90, 180 and 360 day forward rate, Covered Interest Arbitrage (CIA) can be tested using rates (spot, forward and LIBOR) observed in the 4^{th} quarter or arithmetic and geometric mean of rates in each quarter of the year. Since

nominal interest rates used in the test are levels and not rates of change, methods based on change between the same quarters of subsequent years cannot be utilized again. Measure analogous to the sample standard deviation for the differences between the left (LHS) and the right hand side (RHS) of the CIA test $\{[\sum(LHS-RHS)^2]/(T-1)\}^{1/2}$ can be used to find which forward rate leads to the smallest violation of the CIA.

PHASE THREE OF THE PROJECT: PREDICTING FUTURE SPOT EXCHANGE RATES

In the third excel session, approximately a month before the final week, methods of predicting future spot exchange rates are reviewed. An important distinction between simple and compounded interest calculation and the implication on calculating realized rates and estimating future sport rates is emphasized. To be consistent with the way the rates are quoted by law, as annual percentage rate based on simple interest calculation, annualized realized appreciation is calculated as one plus the changes in currency value between subsequent quarters times four, before it is average across quarters. Hence, annualized dollar appreciation between subsequent quarters is define as $s_{\$}^{90} = (S_{¥/\$}^{0} / S_{¥/\$}^{-90} - 1)*(360/90)$.

On the other hand, finding expected spot rate in one year is based on compounded interest calculation, and instead of multiplying one plus expected quarterly appreciation by four it is raised to the fourth power: $E(S_{¥/\$}^{360}) = S_{¥/\$}^{0}[1+E(s_{\$}^{90})]^4$.

Assuming that realized (nominal or real) appreciation or the one implied by relative purchasing power parity or by International Fisher's Effect of by forward premium, calculated over the initial three years of quarterly data will stay the same over the next three years, students are asked to predict sport rates over the following twelve quarters using the above formula. After they are done, they expand the estimation period to include the initial four years and predict spot rates for the following twelve quarters. They keep repeating this process of adding additional year to the estimation period and predicting spot rate over the following twelve quarters until they run out of data. For every estimation period student are free to use the entire or the subset of available data.

To prevent data mining and attempts to better fit the predictions by finding the best length of the estimation period for different prediction periods, once the length of the estimation period has been chosen it cannot be change in subsequent prediction periods unless students come up with the rule based on the information available in the estimation period. For example, if the appreciation in the last year of estimation period is below specified level, predictions are based on appreciation calculated over the last three years. If appreciation exceeds cutoff level, appreciation calculated only over the last year is used for projections.

Given that the formula for predicting future spot exchange rates is exponential function, and that estimated values might grow faster than is observed in the periods of relatively small and stable change in currency values, students are also asked to project future spot rates using OLS regression. Starting with the initial three years of quarterly spot rates estimated OLS Y intercept and slope coefficient are used to project spot rates over the next twelve quarters. In the following iterations estimation period is increased by one year but predictions period remains the following twelve quarters until students run out of data. Once again they can use the entire or the subset of the available estimation data but the length of the estimation period cannot be changed without using rule based on information available in the estimation period.

For every prediction period students are required to compute measure analogous to the sample standard deviation for the differences between the actual spot rates (S) and their estimations [E(S)] based on different expected appreciations, defined as $\{[\sum(E(S)-S)^2]/(T-1)\}^{1/2}$. These measures are then average over all prediction periods for each method of measuring appreciation as well as OLS regressions, in order to rank different prediction methods based on their predictive power.

Since all students use the same data and methods, the only source of variations in their predictions, excluding computational errors, is the length of the estimation period. To stimulate students to experiment with different estimation period or to come up with the rule used to determine the variable length of the estimation period, the team with the lowest average standard deviation measure receives extra 5%. Before

the bonus is awarded the top three teams meet and go over each other's calculations to verify that their results are correct. If the team with the lowest average standard deviation did not do the computations correctly, the next best team with the correct calculations receives the bonus points.

Students have approximately one month to do all these calculations and prepare the presentations that are done during the last week of classes prior to the final exam. Each team has to submit their power point presentation and excel file containing the analysis before the first presentation class via e-mail. All presentations are done using those file to prevent teams that present in the following class from updating their analysis and presentation based on comments made during the first presentation class.

Students are provided with the required topics that have to be addressed in their presentation, but they can include any pertinent information not specified in the instructions for the project. They are asked to rank three methods with the most predictive power, whether the ranking changes in different prediction periods and to compare their result with a priori predictions based on the nature of expected appreciations used to make projections.

Although we expect that forward looking appreciation estimates (forward premium or interest rates, based on expectations about future values) do better than backward looking appreciation estimates (realized appreciation or inflation rates, based on realized values) and that arithmetic average has more predictive power than geometric mean, relative purchasing power parity implied appreciation based on geometric mean usually has the lowest standard deviation averaged over all prediction periods.

CONCLUSIONS

Although some students complain about the amount of the work, those who put in time and effort to understand and learn the relationships between monetary variables, recognize the value of the project. In addition to gaining better understanding of almost every aspect of International Finance that we cover through theoretical discussion or examples in class, they learn valuable excel skills. Most importantly, student who take International Finance class learn so much more about topics that other students cannot learn on their own by following Wall Street Journal or professional press, allowing them to stand up and distinguish themselves during networking opportunities or job interviews.

REFERENCES

Froot, K. (1999), "The 1994-95 Mexican Peso Crisis", Harvard Business School Case Collection.
Johnson, R. & Wichern, D. (2007), Applied Multivariate Statistical Analysis, Pearson Prentice Hall.
Shapiro, A. 2009, Foundations of Multinational Financial Management, John Wiley, 6th ed.

APPENDIX

Analysis of Dollar v Japanese Yen Exchange Rates

Data

Quarterly data on spot and forward indirect quote for yen, CPI[1] and 12 month LIBOR[2] for US and Japan have been collected from Bloomberg from the 4th quarter of 1991 (91.4) through the 4th quarter of 2016 (16.4). From these you can calculate twenty two years of annual rates and annualized quarterly rates.

Methods for Calculating Annual Rates of Change

a) Annual rate of change from the 4th quarter to the 4th quarter of subsequent year. For example, annual rate of change in 1998 will be: 98.4/97.4 - 1.

b) Arithmetic mean for annualized subsequent quarter rates of change. For example, in 1998 it will be: [(98.4/98.3 - 1) + (98.3/98.2 - 1) + (98.2/98.1 - 1) + (98.1/97.4 - 1)] * 4.

c) Geometric mean for annualized subsequent quarter rates of change. For example, in 1998 it will be: $(\{[1+(98.4/98.3-1)]*[1+(98.3/98.2-1)]*[1+(98.2/98.1-1)]*[1+(98.1/97.4-1)]\}^{1/4} - 1)*4$.

d) Arithmetic mean for the same quarters of subsequent year annual change. For example, in 1998 it will be: [(98.4/97.4 -1) + (98.3/97.3 -1) + (98.2/97.2 -1) + (98.1/97.1 -1)] / 4.

e) Geometric mean for the same quarters of subsequent year annual change. For example, in 1998 it will be: $\{[1+(98.4/97.4-1)]*[1+(98.3/97.3-1)]*[1+(98.2/97.2-1)]*[1+(98.1/97.1-1)]\}^{1/4} - 1$.

Assignments

1. XLS file due 2/2. Calculate annual realized nominal appreciations of ¥ and $ (**a-e for each currency**).

2. XLS file due 2/2. Calculate annual forward premiums for ¥ and $ using 3, 6 & 12 month forward rates observed in the same quarter (horizontally). $ forward premiums in 1998 calculated using different methods:

a) $f^{360}_{\$} = F^{360}_{98.4}/S_{98.4} - 1$, $f^{180}_{\$} = (F^{180}_{98.4}/S_{98.4} - 1)*2$ and $f^{90}_{\$} = (F^{90}_{98.4}/S^{98}_{.4} - 1)*4$.

b) $[(F^{360}_{98.4}/S_{98.4} - 1) + (F^{360}_{98.3}/S_{98.3} - 1) + (F^{360}_{98.2}/S_{98.2} - 1) + (F^{360}_{98.1}/S_{98.1} - 1)]/4$,
$[(F^{180}_{98.4}/S_{98.4} - 1)*2 + (F^{180}_{98.3}/S_{98.3} - 1)*2 + (F^{180}_{98.2}/S_{98.2} - 1)*2 + (F^{180}_{98.1}/S_{98.1} - 1)*2]/4$ and
$[(F^{90}_{98.4}/S_{98.4} - 1)*4 + (F^{90}_{98.3}/S_{98.3} - 1)*4 + (F^{90}_{98.2}/S_{98.2} - 1)*4 + (F^{90}_{98.1}/S_{98.1} - 1)*4]/4$.

c) $\{[1+(F^{360}_{98.4}/S_{98.4}-1)] *[1+(F^{360}_{98.3}/S_{98.3} - 1)] *[1+(F^{360}_{98.2}/S_{98.2} - 1)] *[1+(F^{360}_{98.1}/S_{98.1} - 1)]\}^{1/4} - 1$,
$\{[1+(F^{180}_{98.4}/S_{98.4}-1)*2]*[1+(F^{180}_{98.3}/S_{98.3}-1)*2]*[1+(F^{180}_{98.2}/S_{98.2}-1)*2]*[1+(F^{180}_{98.1}/S_{98.1}-1)*2]\}^{1/4} - 1$
$\{[1+(F^{90}_{98.4}/S_{98.4}-1)*4] *[1+(F^{90}_{98.3}/S_{98.3}-1)*4] *[1+(F^{90}_{98.2}/S_{98.2}-1)*4] *[1+(F^{90}_{98.1}/S_{98.1}-1)*4]\}^{1/4} - 1$.
Methods **d** and **e** cannot be used for forward premiums.

3. XLS file due 3/2. Calculate annual inflation rates of ¥ and $ using their respective CPIs (**a-e for each currency**). Methods c and e cannot be calculated if rate of change in any period is less than -100%.

4. XLS file due 3/2. Calculate annual realized real appreciations of $ and ¥. End of period real exchange rate in the 4th quarter of 1998 for methods **a, d & e** is $S_{98.4}' = S_{98.4}[1+(CPI_{98.4}^{\$}/CPI_{97.4}^{\$} - 1)]/[1+(CPI_{98.4}^{¥}/CPI_{97.4}^{¥} - 1)]$.

Real $ appreciation in 1998 for methods **a, d & e** is $s_{\$}' = S_{98.4}' / S_{97.4} - 1$.

End of period real exchange rate in the 4th quarter of 1998 for methods **b & c** is $S_{98.4}' = S_{98.4}[1+(CPI_{98.4}^{\$}/CPI_{98.3}^{\$} - 1)]/[1+(CPI_{98.4}^{¥}/CPI_{98.3}^{¥} - 1)]$.

Real $ appreciation in the 4th quarter of 1998 for methods **b & c** is $s_{\$}' = (S_{98.4}' / S_{98.3} - 1)*4$.

5. XLS file due 3/2. Test if 3, 6 and 12 month forward rate is an unbiased predictor of the future spot rate using **regression** (estimated $S = f(F) = \alpha_0 + \alpha_1 F$ should have Y intercept $\alpha_0 = 0$ and slope coefficient $\alpha_1 = 1$), **residuals** (arithmetic average of differences between S and F should be zero) and **graphical analysis**

(plot S and F on the same graph). Compare staggered data: $F^{90}_{98.1}$ v $S_{98.2}$, $F^{180}_{98.1}$ v $S_{98.3}$, $F^{360}_{98.1}$ v $S_{99.1}$. Use measure analogous to sample standard deviation calculated on the differences between current forward and future spot exchange rate $[(\sum(S-F)^2)/(N-1)]^{1/2}$ to find which forward rate is the best unbiased predictor of future spot.

6. XLS file due 3/2. Calculate relative purchasing power parity implied annual appreciation of ¥ and $. Dollar appreciation in 1988 for methods **a, d and e** would be $[1+(CPI_{98.4}^{¥}/CPI_{97.4}^{¥} - 1)] / [1+(CPI_{98.4}^{\$}/CPI_{97.4}^{\$} - 1)] - 1$. Dollar appreciation in the fourth quarter of 1998 for methods **b and c** would be calculated as $[1+(CPI_{98.4}^{¥}/CPI_{98.3}^{¥} - 1)*4] / [1+(CPI_{98.4}^{\$}/CPI_{98.}^{\$} - 1)*4] - 1$.

7. XLS file due 3/2. Calculate international Fisher's effect implied annual appreciation of ¥ and $. Dollar appreciation in 1998 for methods a, b and c would be $(1 + I_{98.4}^{¥}) / (1 + I_{98.4}^{\$}) - 1$,
$\{[(1+I_{98.4}^{¥})/(1+I_{98.4}^{\$})-1] + [(1+I_{98.3}^{¥})/(1+I_{98.3}^{\$})-1] + [(1+I_{98.2}^{¥})/(1+I_{98.2}^{\$})-1] + [(1+I_{98.1}^{¥})/(1+I_{98.1}^{\$})-1]\} / 4$
and $\{[(1+I_{98.4}^{¥})/(1+I_{98.4}^{\$})]*[(1+I_{98.3}^{¥})/(1+I_{98.3}^{\$})]*[(1+I_{98.2}^{¥})/(1+I_{98.2}^{\$})]*[(1+I_{98.1}^{¥})/(1+I_{98.1}^{\$})]\}^{1/4} - 1$.
International Fisher's effect cannot be calculated for methods d and e.

8. XLS file due 3/2. Test if covered interest arbitrage holds for 12, 6 & 3 month forward rates and 12 month LIBORs for each quarter. Test for the 1st quarter of 1998 would be $1 + I_{98.1}^{\$} = [S_{98.1}(1 + I_{98.1}^{¥})] / F^{360}_{98.1}$,
$1 + I_{98.1}^{\$}/2 = [S_{98.1}(1 + I_{98.1}^{¥}/2)] / F^{180}_{98.1}$ and $1 + I_{98.1}^{\$}/4 = [S_{98.1}(1 + I_{98.1}^{¥}/4)] / F^{90}_{98.1}$. Use measure analogous to the sample standard deviation calculated on the differences between left (LHS) and right hand side (RHS) of the test $[(\sum(LHS-RHS)^2)/(N-1)]^{1/2}$ to find which forward rate leads to the smallest violation of CIA.

9. XLS and PPT files due 4/18. Using available data through the fourth quarter of the previous year estimate expected future spot nominal exchange rates for each quarter of the following 3 years starting at the first quarter of 1995. You can use all or subset of available data (it might differ as volatility of exchange rates in the estimation period changes). Repeat the exercise for each three year period through the first quarter of 2014.
a) Use realized nominal and realized real appreciation.
b) Use expected appreciations implied by 3, 6 and 12 month forward rates, international Fisher's effect and relative purchasing power parity.
c) Use regression estimates of y intercept and slope coefficients for historical exchange rates to project future spot rates.
d) Team with the lowest standard deviation between estimated (use the same method to calculate appreciation but estimation period can vary) and realized exchange rates averaged over all 17 three year testing periods will earn extra 5%.

10. What are the three methods (used to calculate appreciation) with the most predictive power? Does the ranking of methods stay the same in every testing period? Does estimation period change over time? Discuss theoretical differences between arithmetic and geometric means, nominal and real realized appreciations, as well as appreciations calculated in different ways (e.g. realized and RPPP are backward looking while the others are forward looking since they are based on expectations about the future).

11. In addition to e-mailing me the spreadsheet with assignments on indicated dates, each team has to e-mail me their presentation (powerpoint file) and excel file on which it was based before the first presentation class. Each team also has to submit the print out of their presentation.

ENDNOTES

CPI measures price of a market basket of consumer goods and services. Its growth rates represent the inflation. London Interbank Offered Rate (measured in percentages) is recorded each day at 11am & released at 11.45am (London time) as an average of the middle two quartiles of quotations from the banks determined by the ICE (Intercontinental Exchange) Benchmark Administration.