Non-Traditional Monetary Policy’s Effects on Exchange Rates

Covered Interest Parity Empirical Analysis of Non-Traditional Monetary Policy’s Effects on Exchange Rates

An honors thesis submitted in partial fulfillment of the requirements for the degree of a BSBA

By

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Abstract

This research sought to find an economically justifiable relationship between non-traditional monetary policies of the Bank of Japan and the Federal Reserve and the dollar/yen exchange rate. This research utilized the covered interest parity condition in conjunction with a partial least squares structured equation analysis in order to discern any possible relationships between these two phenomena. Indeed, this research found a solid relationship between the non-traditional monetary policies of these central banks and dollar/yen exchange rate. In order to analyze significance, direction, and nature of this relationship this research followed up the partial least squares analysis with bootstrap structural equation modeling. Because of the linear nature of this method of evaluating relationships, it was difficult for this research to discern a consistent and significant pattern in the relationships found in the partial least squares analysis. Future research into this topic should direct towards exactly identifying the nature and method for which these policies affect the exchange rate.

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**Covered Interest Parity Empirical Analysis of Non-Traditional Monetary Policy’s Effects on Exchange Rates**

The severity of the recent financial crisis has left many nations, governments, businesses, and communities in unprecedented circumstances of daunting scale and scope. Large governing bodies such as the international governmental institutions, national government treasuries, and central banks have all likened to championing and implementing macro-policies in an attempt to jumpstart lethargic global and/or domestic markets. A particularly interesting and important topic is that of the national central banks and their innovative, non-traditional monetary policies fabricated to fight such markets. During a time of historically high unemployment levels and unusual levels of austerity in industrialized countries, many central banks have directed upon the public drastic measures to hedge the potential tide of depression. The Impacts of these measures, like quantitative easing and credit easing, on the welfare of the world’s nations over time have far-reaching consequences, for better or for worse.

One of the most controversial aspects of these programs are the implications of currency depreciation. Artificial currency depreciation by a central authority, especially of a currency as powerful as the dollar, has the potential to alter the flow of international trade and investment (Feenstra). Furthermore, current analysis of non-traditional monetary policy’s relationship to currency markets is difficult to assess especially given the lack of current empirical body on the topic. Theories about the relationship between monetary policy and exchange rates are at best outdated in the context of a new monetary environment and may require reanalyzing. Likewise, these new policies may need empirical scrutinizing for, the purpose of, exposing any implications they may have on exchange rates. As of now, there exists little empirical research on the effects of these programs on exchange rates. This is because they have only existed for less than
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a decade. In addition, many industrialized countries, the United States and Japan in particular, exist near or at a condition of liquidity trap, where interest rates are near or at zero. This further complicates any possible comparison from previous monetary conditions in these countries to present conditions. Nevertheless, there exists a literary base for analyzing the possible currency exchange rate outcomes of traditional monetary programs where possible hypothesis can be extracted from and analyzed in context of today’s world of non-traditional policy.

The issue with these new policies are that they rely on theoretical bodies of research of monetary policy during a very-low-inflation economy. As highlighted by Blinder, open market operations of private assets, like those operations of the FED (Federal Reserve) and BOJ (Bank of Japan), all entail an indirect market operation on short-term government securities with something else e.g. foreign exchange intervention, credit easing, corporate bond operations etc. (Blinder, 2000, pp. 1092-1099). During the event of a liquidity trap, where rates on short-term government securities are at their zero lower bound, the size of these operations must become massive to evoke an effective rate of inflation. The continued successive expansion of the QE programs in the US and CME programs in Japan coupled with a lack of real inflation in both countries substantiates this insight on a historical perspective. The subsequent inflation of central bank balance sheets has the consequence of exogenously affecting FOREX rates through capital flight of these central bank generated funds to countries with higher yielding assets as the programs of these central banks depress domestic interest rates. The glut of investments flowing to higher yielding developing countries like Brazil and Russia over the past couple of years corroborates this. This has also had the effect of bloating bank balance sheets with cash where banks would take the proceeds from FOMC operations (Federal Open Market Operations) and stash them back in their FED accounts as excess reserves. This has led to a massive increase in the
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monetary base but a relatively small increase in the higher money measures; this manifests into low responses in inflation. The only precedent to these policies is the two decades long issue of lingering deflation in Japan since the early 1990s and the BOJ’s various policies used to unsuccessfully, combat it. Some could even argue that the EU (European Union) is at the brink of a Japanese style zombie banking system plagued by deflation and bad assets perpetuated by central banks.

The issue of monetary policy and exchange rates has a highly ambiguous literature history and there is often little evidence supporting a relationship between the two except in the case that there exists data of high quality and frequency, a condition more analogous to real world conditions. In one paper, Eichenbaum presents contrasting evidence to existing literature, providing substantial evidence that there indeed exists a relationship between monetary policy and exchange rates given more contiguous and quality data (Eichenbaum, 1995, pp. 975-1009). Dornbusch also provides evidence for monetary expansion giving rise to depreciations in exchange rates under a world of perfect capital mobility and flexible exchange rates (Dornbusch, 1976, pp. 231-244).

This research paper, in interest of condensing variables and workload, will only empirically analyze the Japanese and United States central banks: the Bank of Japan (BOJ) and Federal Reserve (FED) respectively. This research will analyze both central banks’ various non-traditional monetary programs (Comprehensive Monetary Easing (CME) and Quantitative and Qualitative Monetary Easing (QQME) for BOJ, Quantitative Easing (QE) 1, 2, 3 and Operation Twist for FED). This research will utilize data over the time-period starting 11/25/2008 (beginning of QE 1 program) and ending 5/15/2013 (Federal Reserve Bank of St. Louis, 2013). The objective of this research is to analyze and calculate these policy’s effects on the dollar/yen exchange rate.
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Overview

First, this paper will present the various statistical concepts and economic theories that create the backbone of this research as well as alternative theories that this research considered for utilization but ultimately did not use (Statistical Model and Economic Theory Introduction). Next, the Method portion of this project contains a structured discussion of this research’s method of approach to modeling monetary policy and exchange rates. Within Method, a discussion of the basic economic model used by this project (Section I), is followed by a discussion regarding the adaptation of this economic model into a statistically computable model (Section II). Following this, Section III presents data utilized in the final analysis as well as particular methods for parsing and organizing these data. The last section (Section IV) of Method discusses the final models and hypotheses used in the final analysis. Finally, this research presents its results under Results while following this are concluding remarks under Conclusion.

Statistical Model and Economic Theory Introduction

The theory of CIP and the basic determinacies of asset yields (supply and demand of loanable funds) can serve as a simple approach to hypothesizing economic causal relationships. The CIP will be able to act as a justification for causal relationships of asset yields across two countries on exchange rates. In addition, supply and demand of loanable funds will be able to
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justify the causal relationships among demanders and suppliers of loanable funds on asset yields, being the central bank of a country able to act as either (P. Taylor, 1987, pp. 429-438).¹

Theoretical relationships detailed by the CIP and supply and demand of loanable funds can be used to construct a general model. Particular endogenous or exogenous measurable phenomenon classify particular variables, such as the dollar/yen exchange rate. In the best case, all endogenous variables will be statistically as well as theoretically acceptable for confiscation.

The principle logic of these one way causal relationships can be construed around theoretically prefabricated ‘nodes’ or constructs meant to define a particular phenomenon (Cronbach, 1955, pp. 281-302).² These nodes are components of a statistical tool called structural equation modeling. Reflective indicators that then form a linear combination reflected in the construct can

¹ This research pursued other economic and statistical models as well as other statistical platforms but ultimately this research chose not to utilize these in the final methodology employed by this project. Regarding possible alternative economic models, this research explored using balance of payments, uncovered interest rate parity condition (UIP) and portfolio balance theory for possible alternatives to explaining causal relationships among central bank non-traditional monetary programs and exchange rates. Regarding alternative statistical methods, this research explored using traditional regression analysis and non-linear structural equation modeling. This research also considered using other programs like SPSS and WarpPLS as well as using Excel for basic regression.

² E.g. a security market or Forex market.
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define these constructs (Bollen, 2005).\textsuperscript{3} Because of the inherent nature of linearly combined constructs, co-linearity among reflective indicators is to be expected and is supposed to happen. This is because these reflective indicators consign to the same effect and are inherently correlated phenomenon in the real world (Bollen, 2005).\textsuperscript{4} Because of the linear factoring of reflective indicators into constructs, this research will utilize certain quality criteria that have the ability to assess the validity of a postured structural model. Quality criteria such as Factor Loadings, Cronbach’s Alpha, Average Variance Extracted (AVE), and Composite Reliability all have the useful ability to assess a structured construct and its utilization of the relative variance of each factor inputting it. If a particular indicator does not meet a defined threshold, this research can consider theoretical confiscation.\textsuperscript{5}

Using these various constructs, this research can draw causal relationships between theoretically justifiable ‘paths’ representative of real world observations (Brown, 2009, pp. 19-23). Intuitively, a, CIP justified, security yield to exchange rate relationship would entail formative indicators inputting an exchange rate construct. This is because of the two country one spot rate model the CIP defines. In such a model multi, co-linearity can arise because of correlation among reflective indicators relegated to separate nodes for purposes of model structuring (Bar-

\textsuperscript{3} E.g. the yields of various securities factoring into a security market construct.

\textsuperscript{4} E.g. the yield on a 1y government bond correlating with the yield on a 2y government bond.

\textsuperscript{5} Typical thresholds: Factor Loading > 0.63 [very good] (Tabachnick, 2007), AVE > 0.5, Composite Reliability > 0.7, and Cronbach’s Alpha > 0.7 (John, 2002, pp. 305-335).
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clay, 1995, pp. 285-309). This kind of statistical phenomenon is to be avoided when at all possible, however, such formative indicators are yet important if they indeed serve the purpose of describing the sought after real world phenomenon (Bollen, 1991, pp. 305-314).

Following the structuring of a model and the subsequent theoretical confiscation of low quality constructors and/or indicators, a PLS algorithm can then be applied using statistical software such as SmartPLS, developed by Ringle, C.M./Wende, & S./Will, S (2005). The SmartPLS software package has the ability to compute standardized regression weights and correlation coefficients amongst a defined structural model. Based on predicted phenomenon and conjectured relationships, the associations among these structured constructs can be evaluated for validity.6 Pending the validity of these models, this research can consider theoretical alterations to the model’s structure or inclusion of other indicators. After deriving unique estimates of each parameter, this research can conclude the deriving of possible models and use the one most theoretically viable for further applications (Kline, 2011).

The next logical step in analyzing a possible relationship among a structured model is to estimate the strength and direction of the relationship with respect to pre-postured hypotheses. Bootstrapping has this ability to estimate, mathematically, the total effects one construct may

\[ \Delta d_t^{(-)} \rightarrow_{(+)} e_f^{d} t-1 + e_f^{d(-)} t \]

---

6 For example: according to a CIP, structured model it could be expected for a given currency to depreciate relative to another’s given the yields denominated by that currency fall. As such, a hypothesized relationship among the given currency’s security denominated yields with the spot rate of the given currency over the other would be predicted to be positive: \( d_{t-1} \)
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have on another, in the context of a wider structured model. Luckily, the bootstrap algorithm is conveniently included in the SmartPLS statistical package (2005).

Bootstrapping has the ability to estimate the average value of a population’s total effect. That is, the resampling technique of bootstrapping has the ability to re-compute the regression coefficients of a defined relationship, in a structured model, to estimate the relationship’s total effect. This has the capability of estimating the direction and magnitude of the relationship between two nodes, either directly or indirectly. Whereas the PLS analysis is more suitable for determining whether a relationship exists in the first place, the bootstrap analysis intuitively follows the PLS in its ability to evaluate the probability of a relationship, its linearity, and if the relationship can used to estimate the future relationship. In the case of the SmartPLS application, structured models found using the PLS analysis can conveniently apply to the bootstrap algorithm. The bootstrap process can then calculate estimates for standardized regression weights between particular hypothesized relationships.

Typical resampling counts can range from 100 – 5000 resamples and it is mainly up to the discretion of the researcher to utilize an appropriate number (Sawyer, 2005). Furthermore, case count should be equal to the number of cases in a particular data set and thus will vary based on the length of time that encompasses each data set (Sawyer, 2005). Typically, the higher the number of resamples calculated, the lower the standardized error. Artificially inflating numbers of resamples can thus produce misleadingly high t-statistics and consequently a falsely significant mean standardized regression effect. Nevertheless, bootstrapping can be a powerful tool for pinpointing the specific effects of a relationship, or more generally, just the direction of the relationship.
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Method

Section I: Constructing a Theoretical Model Using CIP

The covered interest parity condition (CIP) is the derivation of this research’s theoretical model (Refer to section I for reasoning behind this decision). Because of this, it was important to construct a model conscious of the strengths and weaknesses of the CIP. Section III discusses the compensation of the final model for specific weaknesses of the CIP.

The first step taken in defining a valid model was to create one containing all endogenous and exogenous variables theoretically relevant to the question of currency exchange rates and domestic security yields of Japan and the United States and each country’s monetary programs (Refer to Figure 1). A composition of five security yields were collected that represent available security classes in both countries as well as being security classes somewhat differentiable from the other (refer to Section III for the list of asset classes chosen for each country). This composition of securities from each country are to represent the domestic nominal interest rates of each country as defined in the CIP equation.\(^7\) The next section discusses the method for combining these securities to create a single rate for each country. Next, this research introduced the central bank as an independent actor endogenous to the model. Changes in balance sheet holdings of securities relevant to that central bank’s particular monetary programs define its role in the model as a demander and/or supplier of loanable funds. These changes in balance sheet holdings are a direct consequence of demand and supply of loanable funds by the central bank into the financial market for those securities. Other suppliers and demanders of these securities define exogenous variables and are not of interest to this research. Because the other participants in these financial

\(^7\) CIP general equation: \(\frac{(1+i_d)}{(1+i_y)} \times E_y^\$ = F_y^\$\)
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markets have explicit effects on security yields, it was the purpose of this model to measure the specific efficacy of the central bank’s balance sheet holdings changes on security yields. All other effects assume the role of other suppliers and demanders of loanable funds.8

The basic shape of this model is symmetrical, in that, the indicators and structural shape of the U.S. side of the model is identical to the Japan side; whistle both coalesce into a CIP defined exchange rate.9 Figure 1 shows simple hypothesized ‘relationship directional(s)’ and trends between various variables.

8 For example, if balance sheet holdings of a central bank correlate with 30% of the variation in a particular set of security yields, then the model would assume other suppliers and demanders of loanable funds accounted for the other 70% variation.

9 This does not include the individual latent indicators; these indicators differentiate themselves with respect to the given country. The fundamental model formed by particular constructs and relationship directional(s) are symmetrical.
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Figure 1. Sketch of the CIP based economic model including all endogenous and exogenous variables.
Section II: Accommodating Model for SmartPLS and PLS Structural Equation Modeling

This research used the SmartPLS program’s modeling interface and various statistical literature to derive the statistical structure of the final model, i.e. the mathematically derived structure. The basic economic model based on the CIP discussed in the previous section was adapted to the type of path structuring governed by the SmartPLS software. Figure 1 represents a basic interpretation of the type of compensation used for these statistical methods (refer to Appendix I for a sample screenshot of the final model structure in SmartPLS). One such adjustment made to the economic model was to exclude other suppliers and demanders of loanable funds from the statistical model as exogenous to this research’s objective. The particular research question at hand theoretically justifies the exclusion of these other actors. In another instance, lambda (λ) denotes representations of factor loadings for individual security yields. For the example in Figure 1, the formula of the security yield construct represents linear combinations of these factors.\(^{10}\) λ is the specific variance of each latent variable (Security yield in this case) extracted that is then used as a factor in a linear combination that defines a partial least squares path between the exchange rate construct and the given currency denominated security yield construct. Holistically, you can think of the formula in Figure 1 as a pseudo-weighted average of a given country’s

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\(^{10}\) Note that the individual constructs that define the central bank balance sheets are also defined by various security holdings and inputted into each construct by a factor loading representing extracted variance inputted into the construct; this is not shown in Figure 1.
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domestic currency denominated security yields for a given point in time.\textsuperscript{11} In turn, this weighted average can represent the domestic nominal interest rate the respective country. From the set of factor loadings, SmartPLS can derive, multiple quality criteria such as AVE, cronbach’s alpha, and composite reliability (refer to literature review section for descriptions of these criteria). These criteria can assess the likelihood that the set of individual latent variables should be a representative part of a particular construct. An outcome below a defined threshold for these quality criteria would warrant the removal of low factor load scoring latent variables. This concept was very important as it helped to shape the inclusion of particular variables during set periods throughout the multiple statistical sets administered in the SmartPLS program.\textsuperscript{12}

The SmartPLS program was also important for deeming the dates at which the CIP formula was most empirically viable. In order to adjust for the CIP’s inability to predict short-term exchange rate fluctuations, this research placed lags between all model constructs, both between central bank balance sheet holding measurements and security yield measurements, and between security yield measurements and exchange rate measurements. The next section discusses this.

\textsuperscript{11} This method of defining the CIP within a statistical framework about interest rates of a given country holds up empirically on average, which is all the purpose of this research requires (Thornton, 1989, pp. 55-66).

\textsuperscript{12} In practice, given a particular measurement within a dataset of a certain period, not all data collected for the asserted statistical model would be relevant for that period. For example, the BOJ did not hold significant positions in commercial paper until 1/22/2009. Because of this, factor loadings for that variable up until that time will result in 0.000. This would warrant this indicator’s removal from the model up until 1/22/2009.
Section III: Data

This research utilized a variety of data sources in order to have the most up to date indicators of the highest frequency and validity. In general, this research utilized Indicator data from 7/28/2008 to 5/15/2013. For general indicator data like exchange rates, this researched pulled data from the Trading Economics database (2013). For data regarding certain security yields and Federal Reserve balance sheet data the Federal Reserve Economic Database (FRED) was used (2013). Data regarding the Bank of Japan’s balance sheet data are from the Bank of Japan Time-Series Data Search database (2013). Data of certain U.S. treasury security yields come from the U.S. Department of the Treasury Resource Center (2013). Data for certain Japanese

13 120 days before the beginning of QE 1 operations: 11/25/2008 (Federal Reserve Bank of St. Louis, 2013).

14 3-month CD rate, 3-month LIBOR rate, and 3-month interbank rate for the U.S. and Japan come from the FRED database.

15 The balance sheet holdings of mortgage backed securities (MBS), and US note/bond treasury securities are from the FRED database.

16 BOJ holdings of 1 year and 30 year Japanese government bonds; commercial papers; corporate bonds; and stocks, exchange traded funds (ETF), and Japan real estate investment trusts (J-REIT) held as trust property were pulled from the Bank of Japan Time-Series Data Search online database.

17 The 1 year and 30 year treasury security yields originate from the U.S. Department of the Treasury Resource Center.
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government security yields originate from the Ministry of Finance Japan’s Japanese Government Bonds Data Interest Rate database (2013).¹⁸

All indicators were aggregated frequency wise into one-day increments. This research accounted for missing data or data of different frequencies by the substituting the earliest available measurement for that indicator given a particular date in time.

This research parsed data by pre-determined dates and lags and saved data into comma-delineated sheets (.csv) for importation into SmartPLS. The data was then assigned to constructed models like that of the figure in Appendix I and computed using either the PLS algorithm or the bootstrap algorithm, depending on which project was to use that data.

A particularly important concept used in developing the data sets used in this research was to adjust the measured data points of certain indicators with lags. Data sets contained these lags because of the CIP’s inability to predict short-term interest rates. In a sense, the lags allow time for investors to cover capital movements induced by either the FED’s or the BOJ’s actions and ultimately to more accurately measure the central bank’s effects on to the dollar/yen exchange rate. The lags also permit the model sufficient time to accommodate for ‘overshooting’ of asset prices because of central bank announcements. The lags essentially allow a significant amount of time for investors to hedge or cover their positions so that the economic model of this research is not working within the theoretical model of the Uncovered Interest Parity Condition (UIP) which itself does not hold up to empirical verification (Chaboud & Wright, 2004). The

¹⁸ The 1 year and 30 year Japanese government bond yields originate from the Ministry of Finance Japan’s Japanese Government Bonds Data Interest Rate database.
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CIP does hold during such lags as long as high frequency, high-quality data is used (P. Taylor, 1987, pp. 429-438).

Next, this research conducted a series of statistical experiments to find the most valid period for which to administer a lags. Lags defined the amount of time between the central bank balance sheet holding measurements and the corresponding domestic interest rate measurements, and between the domestic interest rate measurements and the dollar/yen exchange rate measurements. Naturally, since this research is determining the effects of other indicators on the dollar/yen exchange rate, the lag for this indicator is representative of the day it was measured, e.g. day zero.

First, this research used the SmartPLS program and its PLS algorithm to test differing lag dates between an interest rate (CIP) construct and a spot rate construct. Note, the following analysis confiscated indicators with factor loadings < 0.4 (Stevens, 1992) for the purpose of evaluating responses of certain CIP related tests and their quality criteria (Little, 1999, pp. 192-211). Lags of (90) days, (30) days, (15) days, and (1) day were analyzed. Table 1 presents this analysis. Next, because the CIP is inherently a predictor of future spot rates, e.g. dependent on both present interest rates and spot rates, the PLS algorithm was again used to test lags between (90) days, (30) days, (15) days, and (1) day from the past spot rate and the present spot rate. Table 2 presents the results of this analysis. The latter test analyzed the correlation between the past spot rates and the corresponding present ones. This research required a firm control of the correlation between the past and present spot rates in order to fit the economic framework of the model. This is because central bank balance sheet holdings, theoretically, effect domestic, nominal interest
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rates first, and then spot rates. Though the past spot rate is not included in any of the final models, it was important to reduce this exogenous variable’s effects on the measured dependent variable, the present spot rate.

Table 1

<table>
<thead>
<tr>
<th>CIP -&gt; E$/Y Date Lag</th>
<th>AVE(^a)</th>
<th>CR(^b)</th>
<th>R(^2) (^c)</th>
<th>C(\alpha) (^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIP (90) day from spot rate(^e)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (90)</td>
<td>0.226</td>
<td>0.512</td>
<td>-</td>
<td>0.422</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.639</td>
<td>-</td>
</tr>
<tr>
<td>CIP (90) day from spot rate (mod)(^e)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (90)</td>
<td>0.417</td>
<td>0.670</td>
<td>-</td>
<td>0.289</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.529</td>
<td>-</td>
</tr>
<tr>
<td>CIP (30) day from spot rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (30)</td>
<td>0.413</td>
<td>0.656</td>
<td>-</td>
<td>0.374</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.453</td>
<td>-</td>
</tr>
<tr>
<td>CIP (30) day from spot rate (mod)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (30)</td>
<td>0.762</td>
<td>0.903</td>
<td>-</td>
<td>0.873</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.329</td>
<td>-</td>
</tr>
<tr>
<td>CIP (15) day from spot rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (15)</td>
<td>0.433</td>
<td>0.673</td>
<td>-</td>
<td>0.381</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.455</td>
<td>-</td>
</tr>
<tr>
<td>CIP (15) day from spot rate (mod)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (15)</td>
<td>0.775</td>
<td>0.910</td>
<td>-</td>
<td>0.381</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.359</td>
<td>-</td>
</tr>
<tr>
<td>CIP (1) day from spot rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (1)</td>
<td>0.449</td>
<td>0.689</td>
<td>-</td>
<td>0.407</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.451</td>
<td>-</td>
</tr>
<tr>
<td>CIP (1) day from spot rate (mod)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIP Node (1)</td>
<td>0.790</td>
<td>0.917</td>
<td>-</td>
<td>0.882</td>
</tr>
<tr>
<td>E$/Y Node</td>
<td>-</td>
<td>-</td>
<td>0.372</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. The selection process for an appropriate lag between the security yield nodes and the spot rate node in the final run model utilized the data composed in this table.

\(^a\)AVE (Average Variance Extracted) > 0.5 is a generally accepted quality threshold (John, 2002, pp. 305-335)
\(^b\)CR (Composite Reliability) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)
\(^c\)R\(^2\) (Correlation Coefficient)
\(^d\)C\(\alpha\) (Cronbachs Alpha) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)
\(^e\)mod (Modified) refers to quality adjustments made to the PLS model based on factor loading thresholds. If the absolute value of the factor loading for a given variable was less than 0.4 the variable was then confiscated (Stevens, 1992).
Non-Traditional Monetary Policy’s Effects on Exchange Rates

<table>
<thead>
<tr>
<th>E$/Y – (X) days -&gt; E$/Y Date Lag</th>
<th>Quality Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVE&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>E$/Y (90) day from spot rate</td>
<td>-</td>
</tr>
<tr>
<td>E$/Y Node (90)</td>
<td>-</td>
</tr>
<tr>
<td>E$/Y (30) day from spot rate</td>
<td>-</td>
</tr>
<tr>
<td>E$/Y Node (30)</td>
<td>-</td>
</tr>
<tr>
<td>E$/Y (15) day from spot rate</td>
<td>-</td>
</tr>
<tr>
<td>E$/Y Node (15)</td>
<td>-</td>
</tr>
<tr>
<td>E$/Y (1) day from spot rate</td>
<td>-</td>
</tr>
<tr>
<td>E$/Y Node (1)</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. This table presents the data used in the lag selection process for reducing correlation of present spot rates with those in the past. Using these data, this research made a compromise between longer date lags between the spot past to spot present and shorter date lags between the CIP and spot rate present.

<sup>a</sup> AVE (Average Variance Extracted) > 0.5 is a generally accepted quality threshold (John, 2002, pp. 305-335)

<sup>b</sup> CR (Composite Reliability) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)

<sup>c</sup> R<sup>2</sup> (Correlation Coefficient)

<sup>d</sup> C α (Cronbachs Alpha) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)

Referring to Table 1, the R squared correlation metric was highest at the (90) days CIP lag. However, the model accomplished this with a reduction in quality criteria. Furthermore, the (90) day lag spot rate correlated the least with the present spot rate; this is to be expected when the time difference between the two rates enlarges (Refer to Table 2). Refer to Appendix III for screenshot examples of the models computed using the SmartPLS program for the previous analyses.

Next, this research computed appropriate lag dates for between central bank balance sheet holdings and respective security yields. This research utilized (60) days, (30) days, and 0 day lags. Refer to Table 3 for results of the analysis between these two constructs.
### Table 3

<table>
<thead>
<tr>
<th>Holdings -&gt; Yield Date Lag</th>
<th>Quality Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVE&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>FED (60) day from yield</strong></td>
<td></td>
</tr>
<tr>
<td>FED Node (60)</td>
<td>0.756</td>
</tr>
<tr>
<td>$ Securities Node 0</td>
<td>0.588</td>
</tr>
<tr>
<td><strong>BOJ (60) day from yield</strong></td>
<td></td>
</tr>
<tr>
<td>BOJ Node (60)</td>
<td>0.667</td>
</tr>
<tr>
<td>¥ Securities Node 0</td>
<td>0.803</td>
</tr>
<tr>
<td><strong>FED (60) day from yield (mod)</strong></td>
<td></td>
</tr>
<tr>
<td>FED Node (60)</td>
<td>0.753</td>
</tr>
<tr>
<td>$ Securities Node 0</td>
<td>0.725</td>
</tr>
<tr>
<td><strong>BOJ (60) day from yield (mod)</strong></td>
<td></td>
</tr>
<tr>
<td>BOJ Node (60)</td>
<td>0.773</td>
</tr>
<tr>
<td>¥ Securities Node 0</td>
<td>0.802</td>
</tr>
<tr>
<td><strong>FED (30) day from yield</strong></td>
<td></td>
</tr>
<tr>
<td>FED Node (30)</td>
<td>0.726</td>
</tr>
<tr>
<td>$ Securities Node 0</td>
<td>0.586</td>
</tr>
<tr>
<td><strong>BOJ (30) day from yield</strong></td>
<td></td>
</tr>
<tr>
<td>BOJ Node (30)</td>
<td>0.658</td>
</tr>
<tr>
<td>¥ Securities Node 0</td>
<td>0.790</td>
</tr>
<tr>
<td><strong>FED (30) day from yield (mod)</strong></td>
<td></td>
</tr>
<tr>
<td>FED Node (30)</td>
<td>0.719</td>
</tr>
<tr>
<td>$ Securities Node 0</td>
<td>0.984</td>
</tr>
<tr>
<td><strong>BOJ (30) day from yield (mod)</strong></td>
<td></td>
</tr>
<tr>
<td>BOJ Node (30)</td>
<td>0.767</td>
</tr>
<tr>
<td>¥ Securities Node 0</td>
<td>0.790</td>
</tr>
<tr>
<td><strong>FED 0 day from yield</strong></td>
<td></td>
</tr>
<tr>
<td>FED Node 0</td>
<td>0.736</td>
</tr>
<tr>
<td>$ Securities Node 0</td>
<td>0.596</td>
</tr>
<tr>
<td><strong>BOJ -0 day from yield</strong></td>
<td></td>
</tr>
<tr>
<td>BOJ Node 0</td>
<td>0.656</td>
</tr>
<tr>
<td>¥ Securities Node 0</td>
<td>0.805</td>
</tr>
<tr>
<td><strong>FED -0 day from yield (mod)</strong></td>
<td></td>
</tr>
<tr>
<td>FED Node 0</td>
<td>0.729</td>
</tr>
<tr>
<td>$ Securities Node 0</td>
<td>0.986</td>
</tr>
<tr>
<td><strong>BOJ -0 day from yield (mod)</strong></td>
<td></td>
</tr>
<tr>
<td>BOJ Node 0</td>
<td>0.766</td>
</tr>
<tr>
<td>¥ Securities Node 0</td>
<td>0.805</td>
</tr>
</tbody>
</table>

Note. The results in this table indicate the quality of each proposed lag. A lag date of (30) days was utilized in both PLS projects discussed latter on. Refer to Section IV and Appendix II for extended analysis on these choices.

<sup>a</sup> AVE (Average Variance Extracted) > 0.5 is a generally accepted quality threshold (John, 2002, pp. 305-335)

<sup>b</sup> CR (Composite Reliability) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)

<sup>c</sup> R<sup>2</sup> (Correlation Coefficient)

<sup>d</sup> C<sub>α</sub> (Cronbachs Alpha) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)

<sup>e</sup> mod (Modified) refers to quality adjustments made to the PLS model based on factor loading thresholds. If the absolute value of the factor loading for a given variable was less than 0.4 the variable was then confiscated (Stevens, 1992).
The results of this analysis show that the (30) days from balance sheet holdings to the security yield node produce the highest correlation whistle still providing significant quality indicators compared to the (60) days and 0 day alternative lags. Refer to Appendix IV for example models of the models computed in SmartPLS for these results.

Finally, the last analysis employed a composite model to test the (90) day CIP lag with the (30) day balance sheet lags together (refer to Figure 2 above). The numbers placed between the individual blue highlighted constructs and yellow highlighted reflective indicators are factor
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loadings. The numbers placed within the constructs are correlation coefficients ($r^2$). The numbers hovering the relationship directional between any two nodes are the standardized regression coefficients ($\sigma$).

The results of this analysis confirm a strong structural model (refer to Table 4). Subsequent quality modifications resulted in an even stronger model as indicated by the four quality indicators in Table 4. The next section will utilize this model structure to postulate hypotheses for the two statistical methods used in the final analysis: PLS and Bootstrap.

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary of Statistical Results of Final Statistical Model Using 90 and 30 day ‘lags’</strong></td>
</tr>
<tr>
<td><strong>Final Statistical Model</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Model</td>
</tr>
<tr>
<td>$ Security Node</td>
</tr>
<tr>
<td>FED Node</td>
</tr>
<tr>
<td>¥ Security Node</td>
</tr>
<tr>
<td>BOJ Node</td>
</tr>
<tr>
<td>E$/Y</td>
</tr>
<tr>
<td>Model (mod)$^e$</td>
</tr>
<tr>
<td>$ Security Node</td>
</tr>
<tr>
<td>FED Node</td>
</tr>
<tr>
<td>¥ Security Node</td>
</tr>
<tr>
<td>BOJ Node</td>
</tr>
<tr>
<td>E$/Y</td>
</tr>
</tbody>
</table>

Note. This table displays the relative quality and robustness of the final statistical model when the appropriate ‘lags’ are introduced.

$^a$ AVE (Average Variance Extracted) > 0.5 is a generally accepted quality threshold (John, 2002, pp. 305-335)

$^b$ CR (Composite Reliability) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)

$^c$ R$^2$ (Correlation Coefficient)

$^d$ C $^\alpha$ (Cronbachs Alpha) > 0.7 is a generally accepted quality threshold (John, 2002, pp. 305-335)

$^e$ mod (Modified) refers to quality adjustments made to the PLS model based on factor loading thresholds. If the absolute value of the factor loading for a given variable was less than 0.4 the variable was then confiscated (Stevens, 1992).

Section IV: Structural Models and Hypotheses

This research ultimately conducted statistical analysis on a series of four projects. Each project contained a relative number of data sets delineated either by monetary program dates or
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by fixed running windows. This research derived four projects, each defined by one of two hypotheses. One hypothesis is based on the PLS algorithm while the other is based on the bootstrap algorithm. Refer to Appendix II for a detailed list of all projects employed by this research paper.

**Partial least squares structural equation modeling.**

This part of the research conducted two projects for evaluating the existence of a relationship between balance sheet holdings of the FED and the BOJ and the dollar/yen spot rate. Referring to Appendix II, these are projects A and B. Project A utilizes the optimum lag dates calculated in Section III. Project B utilizes an alternate set of lags for the purpose of comparison. ((30) days from balance sheet measurement date to security yield date and (30) days from security yield date to spot rate.) If the computed lag dates are indeed optimum then Project B’s results should approximately represent the tail end of a normal curve that represents the variance accountancy of balance sheet holdings with respect to changes in date lags. Project A’s relationship parameters, on the other hand, should exist near the 50 percentile of the distribution, or the mean. Refer to Appendix II for the exact dates of lags utilized in both projects.

Both projects A and B are 2-week running windows starting 6/23/2009. However, each uses measurements taken earlier due to the (120) lag placed on the balance sheet holding measurements and (90) day lag placed on the security yield measurements. Both projects contain 102 distinct datasets. Each dataset contained a total of 120 days of measurements for each indicator discussed earlier (refer to Section III for the list of indicators used throughout all the projects used in this research). Each dataset was computed using an identically structured model to Figure 2 albeit with indicators of differing measurement dates (refer to Figure 3 for the general outline

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of the models used in these two projects). Each data set contained a series of three computations. Figures 3, 4, and 5 are the general models of which these projects used to compute these. Each figure corresponds to one unique computation.

Figure 3 is a non-manipulated-model while Figures 4 and 5 are manipulated-models that that this research used to compute individual correlations between each central bank’s balance sheet holdings and the dollar yen exchange rate. Referring to Equation 1, these manipulations are done for evaluating individual cases where the sum of the individual simplified, manipulated cases were greater than, or less than or equal to the congregated, non-manipulated model. In one case, Case₂, the sum of the two central banks’ balance sheet holdings ‘s correlation coefficient with the spot rate was greater than when the two central bank’s balance sheets were both factored into the model at the same time, e.g. Figure 3. In another case, Case₁, the sum of these correlation coefficients are less than those in Figure 3. Co-linearity between interest rate nodes and the spot rate can possibly explain Case₂; this can happen when one construct depends on two or more other constructs. A lack of prediction power in the model where correlation coefficients are exceedingly low can possibly explain Case₁.

Equation 1 presents these two cases. It also describes how this research mathematically adjusted for each. Equation 1 denotes these two cases Case₁ and Case₂. Equation 1’s various variables are directly correspond to those in Figures 3, 4, and 5. In both cases 1 and 2, this research multiplied the correlation coefficient of the relationship between the central bank’s balance sheet holdings construct with the interest rate construct with the corresponding correlation coefficient of the relationship between the security yield construct and the spot rate construct. However, in Case₂, this research took extra steps to adjust for possible co-linearity introduced into the model as just previously mentioned might be a problem with Case₂.
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In order to reduce this co-linearity, Projects A and B employed a set of computations to mathematically, count two extreme outcomes of the structured statistical model. For example in one instance, the BOJ’s balance sheet holdings $r^2$ with the spot rate node was held constant and the FED’s balance sheet holdings $r^2$ with the spot rate were assumed to accommodate all co-linearity. This research subtracted the difference in the sum of these two correlation coefficients in

\[
 r^2 = \text{Correlation Coefficient} \\
\text{BOJ : E$/¥ = Correlation of BOJ with E$/¥} \\
\text{FED : E$/¥ = Correlation of FED with E$/¥}
\]

Case 1 \Rightarrow r^2_{3,2} + r^2_{3,3} \leq r^2_{3,1}

BOJ : E$/¥ = r^2_{3,2} \times r^2_1

FED : E$/¥ = r^2_{3,3} \times r^2_2

Case 2 \Rightarrow r^2_{3,2} + r^2_{3,3} > r^2_{3,1}

\xi = (r^2_{3,2} \lor r^2_{3,3}) - r^2_{3,1} = r^2_{3,2} \land r^2_{3,3}

BOJ : E$/¥ = r^2_{3,2} \times r^2_1

FED : E$/¥ = r^2_{3,3} \times r^2_2

\alpha_{i,j} \in \Lambda = \begin{bmatrix} \text{BOJ : E$/¥} & \text{BOJ : E$/¥} \times \xi \\ \text{FED : E$/¥} & \text{FED : E$/¥} \times \xi \end{bmatrix}

\beta_{1,f} \in B = \begin{bmatrix} \left( \frac{\sum_{j=1}^{a_{2,j}}}{\sum_{ij=1}^{a_{ij}}} \right) \times \left( \frac{\sum_{j=1}^{a_{2,j}}}{\sum_{ij=1}^{a_{ij}}} \right) \\
\left( \frac{\sum_{j=1}^{a_{1,j}}}{\sum_{ij=1}^{a_{ij}}} \right) \times \left( \frac{\sum_{j=1}^{a_{1,j}}}{\sum_{ij=1}^{a_{ij}}} \right) \end{bmatrix}

\beta_{1,1} = \text{Adjusted FED Correlation with E$/¥} \\
\beta_{1,2} = \text{Adjusted BOJ Correlation with E$/¥}

H_0: \beta_{1,1} = \beta_{1,2} = 0 \\
H_1: \beta_{1,1} > 0 \land \beta_{1,2} > 0

Equation 1. The set of computations that adjusted for possible co-linearity introduced by the structured statistical model when using the PLS algorightm in SmartPLS.
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Figures 4 and 5 and the correlation coefficient in Figure 3 from the correlation coefficient computed for the FED in Figure 5. In other words, this counting computation biased the correlation coefficient of the spot rate in Figure 3 ($r_{3,1}^2$) to favor the BOJ’s balance sheet holdings variance. Likewise, a similar computation favored the correlation coefficient $r_{3,1}^2$ with that of the FED’s balance sheet holdings variance. Equation 1 represents these biases as a set matrix denoted $A$.

After counting these two extreme cases, the model computed a pseudo-weighted average, weighted based on the percent degree at which one central bank’s correlation coefficient, in both bias cases, encompassed the combined correlation coefficient measurement of the two bias cases

$$
\left( \frac{\sum_{j=1}^{2} \alpha_{2j}}{\sum_{j=1}^{2} \alpha_{1j}} \right)^2
$$

The model then scaled the average of the individual bank’s correlation coefficients

$$
\left( \frac{\sum_{j=1}^{2} \alpha_{2j}}{2} \right)^2
$$

by this percent. The point of this was to congregate the set $A$ in Equation 1 into two easy to compare correlation coefficients that adjust

---

20 Example for FED from Equation 1

21 Example for FED from Equation 1
Non-Traditional Monetary Policy’s Effects on Exchange Rates based on the degree that one central bank’s programs overpowered the other’s. In the case that the two program’s individual correlation coefficients were similar, the pseudo-weighted average would merely serve the purpose of congregating the set $A$.

The model used a set of hypotheses to evaluate these two cases. The bottom of Equation 1 lists these hypotheses. $H_0$ represents the null hypothesis and $H_1$ represents the alternate hypothesis. These hypotheses mainly serve the purpose of evaluating the equation set of Equation 1 and not necessarily for evaluating the economic theory behind them. The purpose of this PLS analysis was to highlight possible correlations between balance sheet holdings of central banks and the spot rate, not to prove an economic principle. Rather, this research designed this analysis to determine if a relationship exists between non-traditional monetary programs of the FED and the BOJ and the dollar/yen exchange rate. Appendix II outlines this purpose. Nevertheless, the hypotheses presented in Equation 1 and the PLS algorithm in SmartPLS, combined, provide the mathematical framework for which to evaluate any mathematical relationship found by the structured statistical model. Refer to Appendix V for example screenshots in SmartPLS of the structured statistical models used for both cases 1 and 2.
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**Bootstrap structural equation modeling.**

Referring to Appendix II, projects C and D utilize the bootstrap statistical method. These projects used identical economic models to those employed in projects A and B. Intuitively, these projects employed similar structured statistical models. The length of lags between the constructs that exist in these projects are identical to those of Project A’s, e.g. the optimal computed lags based on the CIP analysis in Section III. However, these projects utilized different data sets delineated by different dates. Appendix II outlines Projects C and D.

The bootstrap method was applied to a modified data set (composed of differing date delineations compared to the PLS analysis projects). One set corresponds to the entire period of non-traditional monetary policy analyzed by this research (11/25/2008 to 5/15/2013), and one corresponding to dates delineated by the beginnings and endings of non-traditional monetary policies of the FED. Table 5 outlines these dates.

<table>
<thead>
<tr>
<th>Set Number</th>
<th>Set Identifier</th>
<th>Set Start Date</th>
<th>Set End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FED QE 1</td>
<td>11/25/2008</td>
<td>3/18/2009</td>
</tr>
<tr>
<td>2</td>
<td>FED QE 1 Expansion</td>
<td>3/19/2009</td>
<td>8/26/2010</td>
</tr>
<tr>
<td>4</td>
<td>-No Active Policies-</td>
<td>6/22/2011</td>
<td>9/20/2011</td>
</tr>
<tr>
<td>5</td>
<td>Operation Twist</td>
<td>9/21/2011</td>
<td>6/19/2012</td>
</tr>
<tr>
<td>6</td>
<td>Operation Twist Expansion</td>
<td>6/20/2012</td>
<td>9/12/2012</td>
</tr>
<tr>
<td>7</td>
<td>FED QE 3</td>
<td>9/13/2012</td>
<td>12/11/2012</td>
</tr>
<tr>
<td>8</td>
<td>FED QE 3 Expansion</td>
<td>12/12/2012</td>
<td>5/15/2013</td>
</tr>
</tbody>
</table>

*Note. Dates are inclusive. In addition, these are not indicative of dates of cases used in each data set. Projects C and D introduced lags to account for CIP covering periods of balance sheet holdings and security yields.*

The bootstrap approach primarily assessed specific hypotheses regarding the direction of exchange rate movements and the direction of central bank balance sheet movements. This approach is an expansion of the PLS running window analyses. In addition, Projects C and D used...
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the bootstrap approach to observe the magnitude of these changes although these magnitudes were not so much important to this research’s objective as it was a supportive parameter.

Equation 2 outlines the bootstrap algorithm in conjunction with the variables presented in Figure 6. Figure 6 is a simplified statistical model of the actual one used in SmartPLS. (Refer to Appendix VI for an example screenshot of a statistical model using the bootstrap algorithm in SmartPLS.) For each data set, these projects used SmartPLS to compute 999 resamples of each data set; not including the one original sample. Furthermore, these projects used numbers of cases equal to the number of days in each data set, e.g. the number of unique measurements for a particular indicator over the data set’s period.

Equation 2 also proposes a number of hypotheses, one null and two alternatives based on the assumption that balance sheet holdings are increasing on average for both the FED and BOJ. (See Appendix VII for evidence that over the period 11/25/2008 to 5/15/2013 balance sheet holdings for both banks are increasing.) $H_0$ (Null Hypothesis) defines an outcome of the bootstrap model that is counterintuitive to the way foreign exchange markets operate. The null hypothesis describes an outcome where the dollar/yen exchange rate is simultaneously appreciating and depreciating, assuming the balance sheet holdings of both central banks are increasing. The logical equation $\mu_1 \geq 0 \land \mu_2 \leq 0$ defines the null hypothesis; where $\mu_1$ is the mean, estimate of the standardized regression weights (SRW), or total effect, between the BOJ’s balance sheet holdings and the dollar/yen spot rate and $\mu_2$ is that of the FED’s. Simultaneous appreciation and depreciation in the spot rate is counterintuitive to the CIP and any such outcome would constitute some statistical discrepancy or failure in the model’s design. $H_1$ on the other hand refers to an outcome in which the dollar is depreciating with respect to the yen. In this case, both mean, estimated population SRWs are positive. In the case of the second alternative hypotheses $H_2$, both
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mean, estimated population SRWs are negative. This case implies that the yen is depreciating against the dollar.

In the case that balance sheet holdings of the FED and BOJ are not both increasing simultaneously, this research will conduct further analysis that extrapolate from the initial hypotheses postulated.

As a note, because the bootstrap method outputs confidence intervals regarding the mean population effect between two nodes in the statistical model, there could be cases were the confidence interval overlaps both hypotheses; null and alternatives. In this case, this research will carefully deconstruct the confidence intervals into relevant portions corresponding to the relevant hypotheses.\(^{22}\)

---

\(^{22}\) For example: If the confidence interval at the 95% level for the BOJ is between -2.300 and 1.000, then two confidence intervals will be computed, one regarding null hypothesis (-2.300 to 0.000) and one regarding the alternative hypothesis (>0.000 to 1.000).
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\[ i = \text{sample } \# \]

\[ \sigma = \text{standardized regression weight} \]

\[ X = \text{the set of resampled standardized measured effects} \]

\[ o_1 = y_{1,2} \times y_{1,1} \Rightarrow \text{BOJ measured effect} \]

\[ x_{1,i} = [y_{1,2}]_i \times [y_{1,1}]_i \]

\[ [y_{1,2}]_i \in Y_{1,2} = \{[y_{1,2}]_1, [y_{1,2}]_2, \ldots, [y_{1,2}]_n\} \Rightarrow \text{¥ Sec.}(\sigma=1) \rightarrow \text{E}$/¥ \]

\[ [y_{1,1}]_i \in Y_{1,1} = \{[y_{1,1}]_1, [y_{1,1}]_2, \ldots, [y_{1,1}]_n\} \Rightarrow \text{BOJ}(\sigma=1) \rightarrow ¥ \text{ Sec.}(\sigma) \]

\[ x_{1,i} \in X_1 = \{x_{1,1}, x_{1,2}, \ldots, x_{1,i}\} \]

\[ o_2 = y_{2,2} \times y_{2,1} \Rightarrow \text{FED measured effect} \]

\[ x_{2,i} = [y_{2,2}]_i \times [y_{2,1}]_i \]

\[ [y_{2,2}]_i \in Y_{2,2} = \{[y_{2,2}]_1, [y_{2,2}]_2, \ldots, [y_{2,2}]_n\} \Rightarrow \$ \text{ Sec.}(\sigma=1) \rightarrow \text{E}$/¥ \]

\[ [y_{2,1}]_i \in Y_{2,1} = \{[y_{2,1}]_1, [y_{2,1}]_2, \ldots, [y_{2,1}]_n\} \Rightarrow \text{FED}(\sigma=1) \rightarrow $ \text{ Sec.}(\sigma) \]

\[ x_{2,i} \in X_2 = \{x_{2,1}, x_{2,2}, \ldots, x_{2,i}\} \]

\[ \text{BOJ} = 1 \mid X = \{X_1\} = \{x_{1,1}, x_{1,2}, \ldots, x_{1,i}\} \]

\[ \text{FED} = 2 \mid \{X_2\} = \{x_{2,1}, x_{2,2}, \ldots, x_{2,i}\} \]

BOJ Estimated Mean Standardized Measured Effect of the Pop. \( \Rightarrow \frac{\sum_{i=1}^{n} x_{1,i}}{n} = \mu_1 \mid n = \# \text{ of samples} \)

FED Estimated Mean Standardized Measured Effect of the Pop. \( \Rightarrow \frac{\sum_{i=1}^{n} x_{2,i}}{n} = \mu_2 \mid n = \# \text{ of samples} \)

\[ H_0: \mu_1 \geq 0 \land \mu_2 \leq 0 \]

If both bank balance sheet holdings increasing with respect to time

\[ H_1 (\$ \text{ depreciation/¥}) : \mu_1 > 0 \land \mu_2 > 0 \]

\[ H_2 (¥ \text{ depreciation/$}) : \mu_1 < 0 \land \mu_2 < 0 \]

Equation 2. Bootstrap algorithm and accompanying hypotheses.
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**Results**

The following section describes the results from the four projects outlined in the previous section. Each project delineates a section below and are in alphabetical order by the project identifier. Appendix II summarizes the projects employed by this research.

**Section V: Project A PLS 2 Week Running Window**

Referring to Graph 1, all 102 PLS algorithm computations for both the FED and the BOJ from Project A have been inputted as stacked clustered columns. The yellow-clustered columns represent the FED’s balance sheet holdings of MBS and notes/bonds percent correlation with the variance in the dollar/yen exchange rate. The BOJ’s balance sheet holdings of 1 year Japan bills, 30 year Japan bonds, corporate bonds, commercial paper, ETFs, J-REITS, and stocks percent correlation with the variance in the dollar/yen exchange rate are filled as black and stacked on top of that of the FED’s. The stacking is appropriate because the combined variance accountancy of both banks is intuitively a single output from the SmartPLS program. A measure for each bank exists because of the measures taken to reduce multi co-linearity. The stacking also provides a convenient aid in evaluating the potency of these central bank’s programs about the exchange rate. It is important to keep in mind that the measured correlations drawn on the graph refer to balance sheet holdings 120 days before the measurement of the dollar/yen exchange rate, also drawn on the graph in green.

The purple and blue shaded regions in the background of the graph represent the level of the FED’s (purple shade) and BOJ’s (blue shade) monetary programs, as measured by the dollar value of their assets at the 120-day lag corresponding to the date axis. The lag in the balance sheet holdings measurement is consistent with the PLS statistical model’s 120-day lag and the clustered column’s 120-day lag. This project standardized the balance sheet holdings of each
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Bank over the period starting 9/19/2007 and ending 5/15/2013.

On the graph, the FED’s shaded area ascends the plotted area as its balance sheet expands and vice versa, while the graph has inverted the BOJ’s shaded area so that its area descends the plotted area as its balance sheet holdings expand, overlapping any FED actions. The purpose of the inversion was to stay consistent with the CIP theory of inverted effects of two countries’ currency denominated yields when compared in conjunction with the current exchange rate between those two countries.

Furthermore, the graph has drawn the standardized dollar/yen exchange rate as the green line traversing the length of the graph. The date of the dollar/yen exchange rate measurement corresponds to the exact date on the date axis; this is consistent with the statistical model where the exchange rate is a zero day measurement. In addition, the graph standardized the exchange rate over the period starting 8/27/2008 and ending 5/15/2013.

Blue and purple lines populating the upper height of the graph delineate dates of non-traditional monetary program introductions or expansions 120 days before the measure on the date axis, consistent with the stacked columns and shaded

**Figure 7.** Clip from Graph 2. Circa 10/23/2011 to 5/23/2012. Large, yellow correlation stacks correspond to large appreciations in the yen relative to the dollar.

**Figure 8.** Clip from Graph 2. Circa 12/23/2012. Large, black correlation stacks correspond to large depreciations in the yen relative to the dollar.
The graph seems to make a lot of sense. It is consistent with the covered interest parity condition when the structured model introduces lags. In other words, large swings in the dollar/yen exchange rate seem to correspond to large fluctuations in balance sheet holdings of the two banks given the time lag allows positions to be covered. The significant, combined correlation coefficients of the two bank’s balance sheet holdings on the exchange rate backs up this correspondence. Largely yellow stacks correspond to a weakening dollar (Figure 8), and equally yellow and black stacks correspond to a volatile but steadily valued dollar (Figure 9 & 10).

Through another perspective, large swings in the correlation among the central banks’ balance sheet holdings (the stacked clustered columns) with the exchange rate correspond to large swings in the dollar/yen exchange rate drawn on the Graph 1 and define the general logic in the graph. In other words, there appears to be a

Figure 9. Clip from Graph 2. Circa 6/23/2009 to 1/23/2010. Moderate, slightly volatile correlations correspond to a volatile exchange rate within a relatively tight bound.

Figure 10. Clip from Graph 2. Circa 3/23/2011. Id. at Figure 9.
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power relationship between the two. As a definite comparison, comparing the scale of each pro-
gram (the shaded regions) to the exchange rate yields a similar conclusion.
Graph 1. Composite graph of Project A’s PLS analysis results.
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Graph 2. Composite of Figures 7 through 9.
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Section VI: Project B PLS 2 Week Running Window

As a means of making sure the lags introduced into the statistical model in project A are appropriate, another PLS analysis was conducted using shorter lag dates. If consistent with this research’s initial CIP lag tests, the results of the shorter lag dates should cause the correlations among the balance sheet holdings and the spot rate to diminish or not significantly change due to actors on exchange rates not having enough time to cover their positions.

Referring to Graph 3, the patterns in the correlations among the FED and BOJ balance sheet holdings and the dollar/yen spot rate appear to be similar to that of Project A’s (Refer to Graph 1). The oscillation patterns in the correlations among the balance sheet holdings and the exchange rate exists among roughly the same periods in both graphs. Furthermore, in Graph 3, relative to Graph 1, the magnitudes of the humps are roughly the same around the 1/23/2010, 8/23/2010, and 3/23/2011 date markers. Furthermore, there is a significant decrease in the magnitudes of the humps around the 10/23/2011 and 5/23/2012 date markers. Interestingly, the magnitude of the correlation stacks around the 12/23/2012 date marker increased significantly.

An interesting observation appears in Graph 4. It would seem that, referring to Graph 3 with the shorter lag periods, correlations of BOJ balance sheet holdings with the spot rate seem to increase (black stacks rise) while that of the FED’s seem to decrease (yellow stacks fall); relative to that of Graph 1. Differing covering periods of the two countries might be able to explain this. One hypothesis is that, on average, Japanese investors, due to long established non-traditional monetary programs and decades of deflation and official interest rates very near zero are more inclined to cover their positions more quickly as a response to monetary policy announcements than in the US where these programs are quite new. In other words, Japanese investors are more immediately adaptable to monetary schemes in Japan than their counterparts in the US are.
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This could provide an explanation for why balance sheet holding changes of the BOJ would produce more pronounced correlations among shorter lags. However, there could exist a multitude of factors beyond the scope of this research that could provide an explanation for this phenomenon.
Graph 3. Composite graph of Project B’s PLS analysis results.
Graph 4. Comparison of 2-week running window PLS correlation coefficient stacks of FED and BOJ.
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Section VII: Project C Total Time Bootstrap Analysis

Project C utilized the bootstrap analysis method highlighted in Section IV. This analysis further evaluated the possible relationship between changes in balance sheet holdings by the FED and BOJ and the exchange rate found in the PLS structured statistical analysis (projects A and B). More specifically, this analysis provides a direct mathematical interpretation of the significance, level, and direction of any possible relationship between central bank balance sheet holdings and exchange rates that this research could then evaluate with respect to a proposed hypothesis.

This research conducted Project C over the period starting 11/25/2008 and ending 5/15/2013. Consequently, Project C only consists of one data set. This data set represents the majority period for which the FED has been conducting non-traditional monetary policy. This research utilized the SmartPLS program to compute resampled standardized regression weights with respect to the original samples. In total, there are 1000 samples with corresponding regression weights between all possible construct relationships. Graph 5 displays the distribution of resampled total effects between the BOJ’s balance sheet holdings and the exchange rate over the given time period. Graph 6 displays the distribution of resampled total effects for that of the FED.

Next, this research evaluated the t-statistics (computed by taking the original sample and dividing it by the standard error of the resample distribution) of each distribution with respect to the 95% confidence interval.\(^{23}\) This research considered any relationship with a t-statistics less

\(^{23}\) Degrees of freedom equals 1000 so corresponding two-tailed t-statistic at the 95% confidence interval is around 2.000
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than 2.000 to be not significant. If a particular relationship was significant, then this research
would evaluate the mean total effects for the resample distribution. In the case of Project C, both
t-statistics were greater than 2.000 (refer to Table 6). This research then evaluated the mean total
effects as well as confidence intervals of these two distributions with respect to the two hypothe-
ses proposed in Section IV:

\[ H_0: \mu_1 \geq 0 \land \mu_2 \leq 0 \]

If both bank balance sheet holdings increasing with respect to time

\[ H_1 (\$ \text{ depreciation/¥}): \mu_1 > 0 \land \mu_2 > 0 \]
\[ H_2 (¥ \text{ depreciation/$}): \mu_1 < 0 \land \mu_2 < 0 \]

Where \( \mu_1 \) represents the estimated mean total effect of the population of resampled total
effects of the BOJ while \( \mu_2 \) represents that of the FED.

<table>
<thead>
<tr>
<th>Relationship Identifier</th>
<th>( \chi^a )</th>
<th>( \mu^b )</th>
<th>( \sigma^c )</th>
<th>( t^d )</th>
<th>Lower Bound(^e)</th>
<th>Upper Bound(^f)</th>
<th>( H )</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOJ Node ( \rightarrow ) E$/$Y</td>
<td>0.590</td>
<td>0.590</td>
<td>0.022</td>
<td>26.304</td>
<td>0.545</td>
<td>0.635</td>
<td>( \mu_1 &gt; 0 )</td>
<td>( H_0 )</td>
</tr>
<tr>
<td>FED Node ( \rightarrow ) E$/$Y</td>
<td>-0.402</td>
<td>-0.402</td>
<td>0.026</td>
<td>15.360</td>
<td>-0.455</td>
<td>-0.350</td>
<td>( \mu_2 &lt; 0 )</td>
<td></td>
</tr>
</tbody>
</table>

Note. Also refer to Graphs 4 and 5 for graphical depictions of each bank’s resample distributions. Each
distribution represents 999 resamples (+ 1 sample) computed to estimate each bank’s balance sheet
holdings total effect on the dollar/yen exchange rate.

\(^a\) Original sample total effect
\(^b\) Mean estimation of the population total effect based on resample data
\(^c\) Standard deviation of the estimated population total effect
\(^d\) T-statistic (\( \chi / \text{STER} \)): STER is the standard error of the estimation of the population total effect
\(^e\) Lower bound of the two-tailed 95% confidence interval
\(^f\) Upper bound of the two-tailed 95% confidence interval

Referring to Table 6, the analysis fails to reject the null hypotheses. Reason being, over
the time period 11/25/2008 and ending 5/15/2013, the total effect estimation of the BOJ’s bal-
ance sheet holdings effect on the exchange rate is positive. Extrapolating, this implies that bal-
ance sheet holdings negatively related to security yields as balance sheet holdings expanded over
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the period. Furthermore, yields negatively related to the dollar/yen exchange rate, meaning the yen appreciated against the dollar, assuming balance sheet holdings of the BOJ increased. An analogous situation occurs with the FED balance sheet holdings and the dollar/yen exchange rate. Increases in holdings corresponded to an appreciation in the dollar against the yen.

The fact that this analysis fail to reject the null hypotheses is not surprising given the extremely wide fluctuation in the exchange rate over the several year period. The next project (Project D) explores a more in depth bootstrap analysis, with periods partitioned by FED non-traditional monetary policy announcements.

Graph 5. The total effect distribution between the balance sheet holdings of the BOJ and the dollar/yen exchange rate over the period starting 11/25/2008 and ending 5/15/2013 represented as a histogram. The dotted lines on the graph represent the mean as well as the 95% confidence interval bounds of the distribution.
Graph 6. The total effect distribution between the balance sheet holdings of the FED and the dollar/yen exchange rate over the period starting 11/25/2008 and ending 5/15/2013 represented as a histogram. The dotted lines on the graph represent the mean as well as the 95% confidence interval bounds of the distribution.
Section VIII: Project D Bootstrap Analysis FED Project

Equation 1 evaluates the hypotheses presented in conjunction with the data presented in Table 7 for the data sets outlined in Table 5.

Apparent in Table 7 is the broad fluctuation in the direction of spot rate movements accounted for by respective central bank balance sheet movements. The changes in the accepted hypothesis between successive time-periods depictions this. This is not surprising given the wide fluctuation in the exchange rate and the level of balance sheet holdings of both the FED and BOJ over the large time period and even between the shorter delineations used in this project. These large fluctuations are apparent in Graphs 1 and 2.

Because the bootstrap structural equation modeling used in this project is a direct expansion of that of the PLS projects, this research was able to present a more condensed graphical representation of the estimated population total effects with respect to the PLS variance estimation graph. Figures 11 – 16 are condensed graphical summaries of these total effects (Graph 7 is a composite of these figures. It provides a context from which this analysis derived these figures from). Note, because the Bootstrap analysis started 90 days before the PLS analysis, there only exists limited corresponding time-periods in the PLS analysis that could be used for the purposes of overlaying the analyses. Nevertheless, the time-periods have been presented for which data is available; these include sets 2. FED QE 1 Expansion through 7. FED QE 3.
Table 7

<table>
<thead>
<tr>
<th>Relationship Identifier</th>
<th>( \mu^a )</th>
<th>( \sigma^c )</th>
<th>( t^d_a )</th>
<th>Lower Bound( ^e )</th>
<th>Upper Bound( ^f )</th>
<th>( H )</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. BOJ Node -&gt; ES/Y</td>
<td>-0.077</td>
<td>0.134</td>
<td>0.576</td>
<td>-0.340</td>
<td>0.196</td>
<td>( t_a &lt; 2 )</td>
<td>( H_1 )</td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>0.644</td>
<td>0.131</td>
<td>4.906</td>
<td>0.380</td>
<td>0.904</td>
<td>( \mu_2 &gt; 0 )</td>
<td></td>
</tr>
<tr>
<td>2. BOJ Node -&gt; ES/Y</td>
<td>0.931</td>
<td>0.096</td>
<td>9.718</td>
<td>0.733</td>
<td>1.116</td>
<td>( \mu_1 &gt; 0 )</td>
<td></td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>-0.217</td>
<td>0.093</td>
<td>2.340</td>
<td>-0.024</td>
<td>-0.340</td>
<td>( \mu_2 &lt; 0 )</td>
<td></td>
</tr>
<tr>
<td>3. BOJ Node -&gt; ES/Y</td>
<td>-0.331</td>
<td>0.047</td>
<td>7.115</td>
<td>-0.427</td>
<td>-0.240</td>
<td>( \mu_1 &lt; 0 )</td>
<td></td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>-0.049</td>
<td>0.025</td>
<td>1.967</td>
<td>-0.009</td>
<td>0.002</td>
<td>( t_a &lt; 2 )</td>
<td></td>
</tr>
<tr>
<td>4. BOJ Node -&gt; ES/Y</td>
<td>0.595</td>
<td>0.078</td>
<td>7.667</td>
<td>0.440</td>
<td>0.750</td>
<td>( \mu_1 &gt; 0 )</td>
<td></td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>-0.221</td>
<td>0.079</td>
<td>2.791</td>
<td>-0.064</td>
<td>-0.381</td>
<td>( \mu_2 &lt; 0 )</td>
<td></td>
</tr>
<tr>
<td>5. BOJ Node -&gt; ES/Y</td>
<td>0.077</td>
<td>0.026</td>
<td>3.001</td>
<td>0.024</td>
<td>0.127</td>
<td>( \mu_1 &gt; 0 )</td>
<td></td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>0.745</td>
<td>0.361</td>
<td>2.064</td>
<td>-0.070</td>
<td>1.373</td>
<td>( \mu_2 &gt; 0 )</td>
<td></td>
</tr>
<tr>
<td>6. BOJ Node -&gt; ES/Y</td>
<td>0.420</td>
<td>0.288</td>
<td>1.458</td>
<td>-0.143</td>
<td>1.008</td>
<td>( t_a &lt; 2 )</td>
<td></td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>0.003</td>
<td>0.143</td>
<td>0.022</td>
<td>-0.285</td>
<td>0.287</td>
<td>( t_a &lt; 2 )</td>
<td></td>
</tr>
<tr>
<td>7. BOJ Node -&gt; ES/Y</td>
<td>-0.006</td>
<td>0.083</td>
<td>0.069</td>
<td>-0.178</td>
<td>0.155</td>
<td>( t_a &lt; 2 )</td>
<td></td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>-0.545</td>
<td>0.095</td>
<td>5.734</td>
<td>-0.355</td>
<td>-0.735</td>
<td>( \mu_2 &lt; 0 )</td>
<td></td>
</tr>
<tr>
<td>8. BOJ Node -&gt; ES/Y</td>
<td>-0.629</td>
<td>0.041</td>
<td>15.434</td>
<td>-0.711</td>
<td>-0.548</td>
<td>( \mu_1 &lt; 0 )</td>
<td></td>
</tr>
<tr>
<td>FED Node -&gt; ES/Y</td>
<td>-0.156</td>
<td>0.040</td>
<td>3.901</td>
<td>-0.236</td>
<td>-0.076</td>
<td>( \mu_2 &lt; 0 )</td>
<td></td>
</tr>
</tbody>
</table>

Note. Refer to Appendix VIII for graphical depictions of resample distributions for each bank’s balance sheet holdings total effect on the dollar/yen spot rate during the different time-periods.

\( ^a \) Original sample total effect
\( ^b \) Mean estimation of the population total effect based on 999 resamples of original data with case numbers for individual resamples equal to the original data’s corresponding number of cases
\( ^c \) Standard deviation of the estimated population total effect
\( ^d \) T-statistic (\( \chi/\text{STER} \)); STER is the standard error of the estimation of the population total effect
\( ^e \) Lower bound of the two-tailed 95% confidence interval
\( ^f \) Upper bound of the two-tailed 95% confidence interval
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Looking at Figures 11 - 16 and the corresponding entries in Table 7 (relationship identifiers 2. – 7.), linear trend lines of the exchange rate have been overlaid into the graph clips. In addition, Figures 11 – 16 include a yellow, elevated line that represents the combined, standardized quantity of FED and BOJ balance sheet holdings. An increase in FED holdings, holding the BOJ’s constant, would push the line upwards, while an increase in BOJ holdings, holding the FED’s constant, would push the line downwards. Using the various relationship indicators of the PLS analysis and these two other trend lines visual relationships were discerned. Then, mathematical analysis was used to analyze the magnitudes in the changes of the background shaded areas of each bank with respect to changes in the exchange rate (also, corroborated by the PLS variance accountancy) in conjunction with the relationship postulated by the estimation of the population total effect. These two relationships were evaluated with respect to each other to determine if the graphical relationship postulated in the PLS analysis are mathematically substantiated by the bootstrap analysis.

In Figure 11, the bootstrap analysis failed to reject the null hypothesis. Figure 11 defines the period of FED QE 1 expansion policy in the United States starting 3/19/2009 and ending 8/26/2010. Like the PLS analysis, dates of particular balance sheet changes are analyzed with respect to the exchange rate 120 days after. The two partial hypothesis produced by the bootstrap algorithm for this time period are counter intuitive as

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**Figure 11. FED QE 1 Expansion. Program**

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they imply simultaneous appreciation and depreciation in the dollar/yen exchange rate when assuming balance sheet holdings of both banks are increasing. A closer look at Figure 11 will reveal that linearly defining a relationship for this large time-period is difficult, thus, it is not surprising that the bootstrap algorithm failed to reject the null. The general trend (the dotted line) implies a long-term depreciation in the dollar; this trend corroborates the positive estimation of the population total effect of the BOJ node if not accounting for the fact that the BOJ’s balance sheet holding are actually decreasing on average during this period. The FED node effect is negative however and implies dollar appreciation because of increases in balance sheet holdings. It would seem that, during this time-period, the BOJ was scaling back their non-traditional monetary programs with respect to the scale of the FED’s. The stark rise in the prominent edge of the background shade substantiates this. (Note, to read the background shade, the BOJ’s holdings are subtracted from the FED’s so that you read the prominent edge of the blue shade, this is the dark yellow line in the figure.) The null relationship seems to make sense, in that the scaling back of monetary transactions by the BOJ is effectively magnifying the FED’s QE 1 expansion effects on the exchange rate. Consequently, this is causing a general depreciation in the value of the dollar with respect to the yen. That is, although the FED’s estimation of the total effect implies its increases in balance sheet holdings are causing dollar appreciation. Although the FED’s first foray into non-traditional monetary policy was not as substantial as the program’s later successors, the scaling
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back of central bank transactions by the BOJ during this time period effectively outweighed any appreciative effects the model estimation might have substantiated by assigning a negative estimation of the population total effect of the FED.

Referring to Figure 12, the general appreciating trend in the value of the yen continues. The negative partial hypothesis of the BOJ and non-significant FED partial hypothesis, however, do not lend themselves to induce an appreciation in the yen. In fact, based on the estimation of the population total effect, one would believe that the yen would depreciate during this time-period. The upward sloping trend line of the spot rate coupled with a stark rise in FED non-traditional monetary policy accountancy of exchange rate variation in the latter half all demonstrate a counter to the population estimations. The conflicting results of this model could be a result of the volatile nature of the exchange rate during this period.

Continuing on to Figure 13, the period between 6/22/2011 and 9/20/2011 constitute a period of no active policies by the FED. The relatively short time period and the fact during this time-period the FED was not conducting any non-traditional monetary policy makes the results of the bootstrap estimations of the population total effect unexciting. During this period, you could argue that there was a slight depreciation in the yen relative to the dollar, as highlighted by the dotted trend line. Indeed, the sudden shift in the magnitude of the balance sheet holdings of
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the BOJ could corroborate this argument, but the fact that
the exchange rate seems to hold steady during this period
and the fact that the null hypothesis failed to be rejected
both make it difficult to define a possible relationship dur-
ing this time period.

Next, referring to Figure 14, the FED’s Operation
Twist program and the dates that it was active (9/21/2011
– 6/19/2012) are analyzed. The Operation Twist program
was a credit-easing monetary program as opposed to a
quantitative easing one. According to the bootstrap model
and the accompanying hypothesis, of which both partial
hypotheses are significant, the balance sheet changes dur-
ing this time-period were conducive to dollar depreci-ation relative to the yen. Starting from the left, sharp depreci-a-
tion in the dollar follows sudden appreciation in the dollar.
This almost resembles “over shooting” in which investors over adjust to market conditions and
subsequently readjust their positions to a more moderate one. This sharp depreciation is simulta-
neously occurring whistle the exchange rate variance accountancy by the FED’s balance sheet
changes rise significantly. The large yellow stacks highlight the latter. It is interesting that the
large changes in the BOJ balance sheets during this period do not statistically arise to a deprecia-
tion in the yen; although the population total effect of the BOJ node is hardly large. However, it
seems obvious that we would expect to see depreciation in the yen after the large downward

\[
\begin{array}{ccc}
\text{BOJ Node } & \text{E$/Y} & \mu_1 \\
\text{FED Node } & \text{E}$/Y & \mu_2
\end{array}
\]

\begin{array}{ccc}
0.075 & 3.001 & \mu_1 > 0 \\
0.651 & 2.064 & \mu_2 > 0
\end{array}

Figure 14. Operation Twist. Program
dates: 9/21/2011 – 6/19/2012. Graph
dates: 1/19/2012 – 10/17/2012.
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swath of blue shade. This appears to occur during the,
roughly, first third of Figure 14. Nevertheless, it would
seem the FED’s monetary programs are certainly more po-
tent during this period. This is perhaps a consequence of the
credit-easing programs of the FED as opposed to the BOJ’s
mainly quantitative ones at that time. Bolstering this con-
clusion is the fact that the BOJ’s balance sheet holding
changes do not statistically account for much of the varia-
tion in the exchange rate during this period.

Next, Figure 15 refers to the period in which the
FED expanded their Operation Twist credit-easing program.
Both estimations of the population total effect during of this
period are not significant. Looking at the distribution of
population total effect estimations (Appendix VIII) for the
FED, the distribution is highly erratic considering there are many estimations that imply depre-
ciation of the dollar and many that imply appreciation. The BOJ node is significant, however, at
around the 85% confidence level. The positive estimation implies appreciation in the yen relative
to the dollar. This does not seem to make sense considering the large increase in BOJ holdings
during this period and the corresponding drop in the exchange rate, e.g. yen depreciation. In ad-
dition, the considerable up trend in BOJ balance sheet holdings accountancy of exchange rate
variation during this period does not seem to substantiate the bootstrap’s outcomes.

Now referring to Figure 16, it is apparent that the large influx of liquidity produced by
the BOJ’s balance sheet holdings should be causing a large depreciation in the yen relative to the
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dollar. However, there is no significant relationship between BOJ balance sheet holdings and the exchange rate during this period. In fact, it would appear that the FED’s balance sheet holding changes are having a much more substantial effect on the exchange rate than the BOJ’s. This could be a manifestation relatively constant FED holding increases during this period. The inherent consistency in the FED’s QE 3 program could have indirectly amplified any effects the BOJ’s holding increases might have had on the exchange rate. Another interesting observation is relevant to the distribution population estimations. Referring to Appendix VIII, the BOJ’s distribution kurtosis appears flat and spread out. Juxtaposed to the FED’s distribution where the kurtosis of the distribution implies a strong central relationship among a tight confidence interval, the BOJ’s actions during this period seem to have little effect on the exchange rate.

Figure 16. FED QE 3. Program dates: 9/13/2012 – 12/11/2012.
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Graph 7. Composite of Figures 11 through 16.
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Conclusion

It would seem that linearly defining a relationship between the balance sheet holdings of the BOJ and FED is extremely difficult. In fact, there may be some nonlinear relationship in play here in which outside investors are either exponentially amplifying the effect that these programs have on the exchange rate, or in effect mollifying them as they take speculative actions against central bank programs. The mollifying effect may be more applicable to the BOJ’s actions where, as Blinder said, when a country exists near or at a liquidity trap, central bank transactions must become massive to invoke any kind of significant effect on domestic inflation. Nevertheless, there most definitely appears to be some relationship between central bank non-traditional monetary programs and exchange rates. This is directly apparent throughout the PLS analysis results and graphically throughout Graph 1.

The subject of relating non-traditional monetary policy to exchange rates is indeed difficult. However, I do believe this research provides compelling evidence that a relationship does exist. I would recommend further research into this subject to target defining and testing particular models that could help explain the exact relationship between these two phenomenon.
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References


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Appendix I

Figure I.1. Screenshot of structured statistical model in SmartPLS.
## Summary of Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Purpose</th>
<th>Time Frame</th>
<th>Lags</th>
<th>Type</th>
<th>Period</th>
<th># of Sets</th>
<th>Missing Data</th>
<th>Quality Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 2 week running window PLS</td>
<td>Measure correlation of central bank balance sheet holdings with variance in spot rate</td>
<td>6/23/2009 – 5/7/2013</td>
<td>Holdings to Spot</td>
<td>120 days</td>
<td>102</td>
<td>Earliest Measure</td>
<td>Yes</td>
<td>N/A</td>
</tr>
<tr>
<td>B. 2 week running window regression (alternate)</td>
<td>Offer alternative lag dates to project A. for confirming optimal CIP lags</td>
<td>6/23/2009 – 5/7/2013</td>
<td>Holdings to Spot</td>
<td>30 days</td>
<td>102</td>
<td>Earliest Measure</td>
<td>Yes</td>
<td>N/A</td>
</tr>
<tr>
<td>C. Total time bootstrap analysis</td>
<td>Estimate regression weights for purpose of evaluating hypotheses</td>
<td>3/25/2009 – 5/15/2013</td>
<td>Holdings to Spot</td>
<td>120 days</td>
<td>1</td>
<td>Earliest Measure</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>D. FED project date delineated bootstrap analysis</td>
<td><em>ld.</em> at project C purpose</td>
<td>3/25/2009 – 5/15/2013</td>
<td>Holdings to Spot</td>
<td>120 days</td>
<td>8</td>
<td>Earliest Measure</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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*a* Statistically significant factor loadings for the purpose of evaluating the relevance of a particular variable to the presented statistical model are shown to be 'very good' when the absolute value of the factor loading is greater than 0.63 (Tabachnick, 2007).

*b* Bootstrap population estimations between constructs are considered statistically significant if the t-statistic is greater than 2 (John, 2002, pp. 305-335)
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Appendix III

Figure III. 1. CIP node (90) days from the exchange rate.

Figure III. 2. CIP node (90) days from the exchange rate. Modified for quality.

Figure III. 3. Past exchange rate (90) days from present exchange rate.
Appendix IV

Figure IV. 2. Screenshot from SmartPLS. (30) day lag between balance sheet holdings of BOJ and security yields.

Figure IV. 2. Screenshot from SmartPLS. (30) day lag between balance sheet holdings of BOJ and security yields. Modified for quality.
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Figure IV. 3. Screenshot from SmartPLS. (30) day lag between balance sheet holdings of FED and security yields.

Figure IV. 4. Screenshot from SmartPLS. (30) day lag between balance sheet holdings of FED and security yields. Modified for quality.
Appendix V

Figure V. 1. Screenshot of structured statistical model in SmartPLS. Example model of case 1. Furthermore, the model removed the Japanese 30-year bond, 1-year bill, ETF, and J-REIT indicators for statistical quality.

Figure V. 2. Screenshot of structured statistical model in SmartPLS. Example model of case 1 with FED branch removed. Furthermore, the model removed the Japanese 30-year bond, 1-year bill, ETF, and J-REIT indicators for statistical quality.
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**Figure V. 3.** Screenshot of structured statistical model in SmartPLS. Example model of case 1 with BOJ branch removed.

**Figure V. 4.** Screenshot of structured statistical model in SmartPLS. Example model of case 2. Furthermore, the model removed the US CD and interbank indicators for statistical quality.
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Figure V. 5. Screenshot of structured statistical model in SmartPLS. Example model of case 2 with FED branch removed.

Figure V. 6. Screenshot of structured statistical model in SmartPLS. Example model of case 2 with BOJ branch removed. Furthermore, the model removed the US CD and interbank indicators for statistical quality.
Figure VI. 1. Screenshot of structured statistical model using the bootstrap algorithm. The data set used in this model contains data from 12/12/2012 to 5/15/2013 and represents the period in which the FED’s QE3 expansion was active. This model removed the 30-year Japanese government bond, 1-year bill, and ETF and J-REIT holdings of the BOJ for statistical quality.
Figure VII.1. On average, the FED increased its holdings of assets over the period 9/12/2007 to 5/15/2013 as indicated by the linear trend line. However, the rate of increase in these holdings started to diminish around 9/1/2010 as indicated by the inflexion point of the second-degree polynomial trend line.

Figure VII.2. From 9/15/2007 to 5/15/2013, on average, the BOJ increased its holdings of assets over time. However, from around 9/15/2007 to 3/1/2009, referencing the second-degree polynomial trend line, the BOJ was decreasing their holdings of assets. After around 3/1/2009, the value in the BOJ’s assets started to increase at an increasing rate.
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Appendix VIII

1. BOJ

2. BOJ

3. BOJ

4. BOJ

1. FED

2. FED

3. FED

4. FED
Table VIII.1. The number in the title refers to the set number corresponding to FED program dates of Project D. Table 5 outlines these dates.