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FORECASTING FOREIGN CURRENCY EXCHANGE RATES FOR DEPARTMENT OF DEFENSE BUDGETING[1]

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ABSTRACT. This paper examines the opportunity cost of applying simple averages in formulating the Department of Defense (DoD) budget for foreign exchange rates. Using out-of-sample validation, we evaluate the status quo of a center-weighted average against a Random Walk model, ARIMA, forward rates, futures contracts, and a private firm's forecasts over two time periods extending from Fiscal Year (FY) 1991 to FY 2014. The results strongly indicate that four of the alternative methods outperform the status quo over the shorter time period, and three methods for both time periods. Furthermore, a non-parametric comparison of the median error demonstrates statistical similarities between the four alternative methods over the short term. Overall, the paper recommends using the futures option prices to decrease forecast error by 3.23% and avoiding a $34 million opportunity cost.

INTRODUCTION

Uncertainty engulfs the resource planning process to meet expected needs as individuals, companies, and governments each face this dilemma in deciding how best to allot resources to their requirements. Many vested-interests complicate a government's budget allocation while the process's complexity increases when government budgets for those requirements in the home currency and expense for those requirements in a foreign currency. The ambiguity

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of the future exchange rate between the two can induce further variability resulting in a resource allocation inconsistent with resource needs. Inconsistency between an allocation and needs results in an opportunity cost as other requirements lose budget authority from inaccurate exchange rate estimates. This paper examines current DoD foreign exchange rate forecasting practices and analyzes five alternatives methods: a Random Walk, ARIMA, Forward Rates, Futures, and a Private Firm's Forecasts.

The DoD operates in every time zone and in every climate around the globe at more than 5,000 different locations or sites. In executing the US strategy across the globe, the DoD incurs requirements denoted in local currencies. For FY 2013, the DoD budgeted $5.5 billion for foreign currency with an increase to $5.6 billion in FY2014. In order to reduce the variability between the estimated and actual exchange rate, Congress authorized a foreign currency fluctuation (FCF) account in FY79 (Department of Defense, 2011). The DoD uses this account to disburse additional funds when the exchange rate budgeted is insufficient or collect excess funds for budgeted surpluses. The FCF held $1.1B for FY2013 and $1.0B for FY2014. The FCF account represents the opportunity cost of inaccurate estimates.

In order to reduce the size of the FCF account, this paper reviews the current DoD forecasting process as well as the academic literature on exchange rate forecasting. A vast literature on foreign exchange rate forecasting exists, but we will only touch on some promising methods due to the limitations in the federal budget process (e.g. the timing between forecasting a rate and the passing of a federal budget or computational requirements). Exploring options available in the private sector provides additional context to the DoD's procedures. Next, we review five methods from the literature to compare against the status quo. These methods were chosen based on applicability to the federal budget process, ease of use, and academic research. Each method compares a forecasted budgeted rate to the actual rate by the absolute percent error (APE) between the two rates. An APE allows for comparison between the different currencies' values (e.g. 100 Yen/US Dollar versus 0.6 Euro/US Dollar). The methods are then evaluated against each other and the status quo before scrutinizing whether each method is statistically different than the other. The paper concludes with a recommendation on which method the DoD should adopt.

LITERATURE REVIEW

Government entities are not unique in facing exchange rate risk exposure as the growth of multinational enterprises has grown with globalization (Caves, 1996). Private firms face transactional and operational exposure to foreign currency fluctuations much like the DoD but these firms have more options to mitigate the risk of an unfavorable rate. Transaction exposure is the exchange rate risk a contract possesses over a well-defined and relatively short time horizon. Firms mitigate this exposure through the use of forward contracts, future contracts, money market hedge, and options (Bodnar, 2014). Operations exposure is the exchange rate fluctuation impact on a firm's business model. While transaction exposure concerns contract instruments, operations exposure focuses on marketing, product pricing, supply chains, and production (Bodnar, 2014). Private firms still use forecasting, though, for sensitivity, risk, and uncertainty analysis on current or potential assets.

Private firms can choose from a plethora of options, however, most of the options available to private firms do not apply to the DoD. The federal budget process requires the President to send the next fiscal year's budget to Congress by the first Monday in February (a fiscal year is from 1 October – 30 September, spanning two calendar years) (Office of Management and Budget, 2013). In the months previous to February, the departments of the executive branch (the DoD is one such branch) plan their requirements for the next fiscal year. The budget forecasts exchange rates one to two years ahead in order to translate requirements in foreign currencies to US dollars (e.g. a forecast from October 2016 will predict exchange rates for the next fiscal year from 1 October 2017 to 30 September 2018). Congress authorized the Foreign Currency Fluctuation (FCF) account in FY79 to alleviate the adverse effects of significant currency variations as a small holding account between fiscal years. While the FCF buffers the variability between the budgeted exchange rate and actual exchange rate, fiscal law sets more restrictions on the use of appropriated funds than a private firm has on its own funding. For example, currency options and the use of derivatives are prohibited by law (Groshek and Felli, 2000). Appropriations must be obligated in the year of execution for current requirements in order to satisfy the bona fide needs rule (The Judge Advocate General's Legal Center and School, 2014). This precludes the DoD from purchasing options contract during budget formulation. Similarly, the DoD may only use forward contracts if the US Treasury has a forward rate agreement for the specific currency (Department of Defense, 2011). Furthermore, stakeholders outside of the DoD control the decision to locate military bases. National priorities, international alliances, and strategic importance outweigh the cost efficiency of locating military bases in favorable exchange rate locales. The lack of available exchange rate mitigation options limits the DoD to forecasting exchange rates.

How should the DoD employ an exchange rate forecast? The academic literature illuminates possible methods. A seminal paper by Meese and Rogoff (1983), though, casts a shadow over the ability to predict exchange rates as tested against out-of-sample data. They found the Random Walk model (the dependent variable is a function of the last observation plus an error term) performs no worse than the univariate time series models, unconstrained VAR, or candidate structural models in forecasting real exchange rates (Meese and Rogoff, 1983). Subsequent studies support Meese and Rogoff's findings as forecasts based on ex ante (before the exchange rate is set) expected changes perform poorly and measuring accuracy by time-varying coefficients with the same data do not overturn Meese and Rogoff's conclusion (Evans and Lyons, 2005; Moosa, 2013; Moosa and Burns, 2014). For most of last few decades, the DoD exercised a naïve based approach to forecasting exchange rates, similar to a random walk (Groshek and Felli, 2000). The DoD selected the most favorable rate (the most US dollars per unit of foreign currency) observed in the months prior to the budget submission. This approach, however, proved controversial as Congress had concerns about whether the DoD's method for selecting foreign currency rates has produced realistic estimates in its budget submissions (Government Accountability Office, 2005). The GAO investigated the DoD process in 2005, and found the method, "underestimates the impact of foreign currency fluctuations and therefore results in a budget submission that does not realistically reflect funding requirements (Government Accountability Office, 2005)." As a result, the DoD abandoned the naïve approach in 2005 for the currently used center-weighted average (detailed as the status quo below). Does the center-weighted average, though, produce more realistic estimates in its budget submission than the naïve based approach?

The academic literature and DoD studies contain evidence of methods that have shown promise over a naïve based approach. Moosa and Burns demonstrate some models outperform the Random Walk when measuring forecast accuracy in terms of rate direction and in terms of profitability (Moosa and Burns, 2014). Engel, Mark, and West emphasize the Random Walk benchmark is improper as models of this type should have low predictive power (Engel et al., 2007). Rossi provides a review of recent literature on exchange rate forecasting and finds some predictability with one or more of the following: the predictors are Taylor rule or net foreign assets, the model is linear, and a small number of parameters are estimated (Rossi, 2013). Over a shorter time horizon, applying Bayesian model averaging shows large gains over the Random Walk benchmark (Corte et al., 2008). Advanced prediction methods like artificial neural networks (self-learning algorithms trained on historical data) demonstrate robust exchange rate predictions in the midst of outliers (Majhi et al., 2012). However, the short time horizon for Bayesian model averaging and the complexity of an artificial neural network preclude the use of these methods for this study. In 1998, Gerald M. Groshek and James C. Felli of the Naval Postgraduate School (NPS) found forward foreign exchange rate contracts and purchasing currency option outperformed the DoD's naïve based approach with a cost reduction of 3.5% and 6.4%, respectively (Groshek and Felli, 2000). The results of the above research lead to the possibility of positive results compared to Meese and Rogoff's original study.

Auction theory provides a method to build upon Groshek and Felli's work with option markets without needing to purchase options. The international exchange market for currencies acts as an auction, and the future options on currencies may give insight into forecasting the exchange rate. If there are many traders for the currency, the option market can aggregate each trader's estimated price on the underlying asset (Psendorfer and Swinkels, 2000). Furthermore, markets economize information by generating, discovering, and using relevant knowledge to coordinate economic activity through time (Ubaydi and Boettke, 2012). The option price then acts as a signal of the market's approximation for the currency's future exchange rate. Although the actual purchase of options by the DoD is improper and against regulations, the price of such options aggregates the pertinent information of those traders buying and selling the option and provides a possible forecast estimate of the underlying currency.

METHODS

The literature review provided a variety of methods for forecasting foreign exchange rates. The goal is to compare the accuracy of these methods to the DoD's status quo. The Random Walk model demonstrated robustness across time and sample size. The literature also suggested advanced forecasting techniques had some benefits over the Random Walk model. Forward rates had success when applied to a DoD environment. Though regulations prevent the purchase of options, the option market may provide an adequate forecasted rate that aggregates all available information available to traders. Finally, the DoD is also interested in the forecasts of a private firm to each of these methods. Thus, five methods (Random Walk, ARIMA, Forward Rates, Futures, Private Firm Forecast) are compared to the DoD's current method of forecasting a budgeted exchange rate. A description of each method follows.

The DoD's current method (status quo) is a center-weighted average between a five year average exchange rate and the rate 12 months prior. Practically speaking, this method allowed for short term (12 month) and long term (five years) trends in forecasting exchange rates while adjusting the weight between the two with observed exchange rates. This technique pulls the average monthly exchange rate for the past five years and the exchange rate 12 months prior from the Federal Reserve's H.10 foreign exchange report. Each of these is weighted equally and combined to form a budgeted exchange rate.

The next step calculates a budgeted rate using the equal weights over the last several years to find the forecast error from equal weighting. The forecast error is the sum of squared errors (SSE) between the forecasted rate and the actual rate from previous forecasts. The formula is:

$$SSE = \sum (R_{Forecasted} - R_{Observed})^2$$

where $R_{Forecasted}$ is the forecasted exchange rate and $R_{Observed}$ is the actual exchange rate.

Next, a linear optimization determines the weights between the five year average and rate 12 months prior to minimize the forecast error, by iteratively changing the weights. Finally, the results are reviewed for any long term trends or changes to the currency. Adjustments are made to account for fundamental changes (e.g. changing the peg of the Kuwaiti Dinar from the US dollar to a basket of currencies in May 2007 caused the five year average to be a three average in 2010).

The first alternative method utilizes ARIMA (auto regressive, integrated, moving average) modeling as an advanced form of time-series forecasting prior to testing the Random Walk model (an ARIMA (0,1,0)). Just as the status quo used two separate averages with optimized weighting, the motivation to apply an ARIMA came from exploring possible techniques for improving on simple averages. The general ARIMA equation is:

$$(1 - \varphi_1 B)(1 - B)Y_t = c + (1 - \theta_1 B)e_t$$

This is an ARIMA(1,1,1) model with φ_1 as the auto regressive parameter, θ_1 as the moving average parameter, and (1-B) as the differencing parameter. *B* represents the lag operator to incorporate the previous time series element ($BY_t = Y_{t-1}$ for all t>1). The e_t variable is an error term and is assumed to be independent and identically distributed along a normal distribution with a mean of zero. The constant, *c*, is an overall level for the dependent variable and represents stationarity (the data's mean and/or variance are approximately horizontal along the time axis). Annual forecasts were conducted. The model group allows for testing 27 separate ARIMA models for each currency by fiscal year (from ARIMA(0,0,0) to ARIMA (2,2,2) or 3^3 possibilities). When choosing between ARIMA models, the Akaike Information Criterion (AIC) provides a measure for choosing the most adequate model (Burnham and Anderson, 2004). The AIC is an estimate of the information loss in a model and is calculated by:

$$AIC = -2LogLikelihood + 2k$$

The term k is the number of estimated parameters, including intercept and error terms in the model. A lower AIC value guards against information loss and selects the better model at estimating (SAS Institute Inc, 2014). The model with the lowest AIC provided the estimate for the budgeted rate.

The Random Walk method is a special type of ARIMA model and is the second alternative method analyzed. This method is very similar to DoD forecasting prior to 2005 with a nuance. Instead of using the most favorable rate, this method uses an ARIMA(0,1,0) to represent the Random Walk (built upon the observed exchange rates for the prior year). It lacks autoregressive and moving average parameters but maintains a difference parameter (Nau, 2014). Random Walks can have extended periods of apparent trends which unpredictably change direction. The random walk equation is:

$$Y_t = Y_{t-1} + \varepsilon_t$$

where the forecasted value, Y_t, equals the previous value, Y_{t-1}, plus an error term, ε_t.

In order to generate a budgeted rate, we use historical exchange rates to derive an error term. This error term is added to the last data point for the exchange rate to create a budgeted exchange rate.

The third alternative method is forward rates. Interest rate parity determines a forecasted rate based on the idea the forward (future) rate can be predicted based on the spot (current) rate and the ratio of interest rates from one country to the other (Feenstra and Taylor, 2008). It is a basic method for calculating forward rate contracts. The following equation was employed to calculate the forward exchange rate used for the budgeted rate:

$$r_j = r_K^{j=0} \frac{1 + i_j}{1 + i_{j=0}}$$

The equation gives the forward exchange rate, r_j, for country *j* using the US dollar spot rate, $r_K^{j=0}$, in annual terms of year *k* and the interest rate, i_j, of country *j* in the month of October before the fiscal year of interest (Feenstra and Taylor, 2008). As an example, for FY06 the Euro forward rate is 0.720868049 as calculated with an $r_K^{j=0}$ of 0.803988 Euro to US dollars annual exchange rate from the FRB H.10 report, an i_j of 3.6893 and a $i_{j=0}$ of 4.23 as the long-term interest rates per annum in October from the OECD monthly monetary and financial statistics dataset.

The fourth alternative method is futures. While the purchase of options (futures) contracts is prohibited, their price may have some measure of predictive capability. The intuition of using futures data is the price of the futures contract aggregates the information of the buyers and sellers of the contract in divining the true value of the underlying currency. Quandl provided data containing the daily futures prices on currencies from the Chicago mercantile Exchange (CME). The futures contract prices differ according to time and contract expiration day. In order to create a historical futures series, the contracts must be blended into a continuous futures contract by combining. Combining the individual futures contracts (or 'rolling' the contracts) can follow different rules depending on the analysis. Economic forecasting uses the "first day of month" and "calendar-weighted rolling" rules. The "first day of month" roll method combines futures on the first day of the contract delivery month or on the contract end date, whichever is sooner (Quandl, 2015). The "calendar-weighted rolling" is a price adjustment to negate the discontinuities in contract prices of the successive underlying futures contracts. The method allows for transitioning from one contract to the next over 5 days where the first contract is weighed 100% on day 1 and 0% on day 5. The opposite is true for the second contract. The percent shifts by 20% each day between the first and second contract. Using the "first day of month" and "calendar-weighted rolling rules" provides a continuous data set for analysis (Quandl, 2015). The data contains daily settle prices, which was averaged for the month of October as the budgeted rate for the following fiscal year.

The last forecasting method comes from a private company.[2] The DoD currently uses the company's materials price forecasts in developing cost estimates for procurement or operations and support (e.g. shipbuilding) (Horowitz et al., 2012). This company also provides an analysis service of how world economic events, trends, and developments affect businesses and countries to include forecasts of foreign exchange rates. Using past forecasts, this research compared the actual to predicted exchange rates from the company. Forecasts from the company, though, do not provide insight into the company's methodology. The company publishes forecasts quarterly with quarterly forecasts two years from the published date and annual forecasts nine years from the published date. This research applied the annual forecasts as a simulated budgeted rate and compares that rate with the actual monthly rates of the year in question.

Data for these alternatives came from a number of sources and dictated two separate time periods of analysis. Table 1 lists data sources, which methods employed the source, the foreign currencies used, and the time frames of the source.

TABLE 1
Data Sources

Data	Model	Countries	Time Period(s)
Undersecretary of Defense, Comptroller (USD,C) Foreign Currency Fluctuation Report	Status quo budgeting rates and adjusting rate	Denmark, the European Union, Iceland, Japan, Norway, Singapore, South Korea, Turkey, and the United Kingdom	FY2006 -2014
Federal Reserve Foreign Exchange Rate-H.10	ARIMA, Random Walk, and forward	Denmark, the European Union, Japan, Norway,	FY2006 -2014, FY1991 - 2012

	rate	Singapore, South Korea, and the UK	
Quandl	CME futures market settlement prices	European Union, Japan, and the UK	FY2006 - 2014, FY1991 - 2012
Organization for Economic Co-operation and Development (OECD)	Long term interest rates, percent per annum from the StatExtracts online database for the forward rate model	Denmark, the European Union, Japan, Norway, South Korea, and the UK	FY2006- 2014, FY1991 - 2012
Private Firm's Forecasts	Private firm method	European Union, Japan, South Korea, and the UK	FY2006 - 2014

There are two time periods of analysis: FY06 to FY14 and FY91 to FY12. Data availability across all sources dictated the time periods. Furthermore, each data set was transformed into an annual mean by currency for each year in order to align the forecasting techniques with the federal budget process (only one forecasted rate is employed for the annual budget rather than a rate for each forecasted month). Investigating the effect of evolving the budget process from using a single forecasted rate for the entire year to a schedule of rates depending on factors such as seasonality may prove fruitful, but is beyond the scope of this paper. The FY06 to FY14 period contains all the methods for comparison with each available currency. A second comparison is then done between the Euro, Pound, and Yen as each method has these currencies during this shorter time period. For the longer period, only the Pound and Yen are compared as data for this time frame was only available for these two currencies. The OECD long term interest rates did not have Japan's rates prior to 1989.

The comparison focuses mainly on the median of the APE due to the kurtosis of the results (results were skewed and did not demonstrate evidence of a normal distribution). The APE is calculated by:

$$APE = \left|\frac{X_{actual} - X_{forecasted}}{X_{actual}}\right|$$

An arithmetic mean APE is calculated for each method in the shorter period before determining the median APE for each method over both periods. The research then compares the accuracy of forecasting exchange rates on a monthly basis. The monthly period is determined by the frequency of reviews the DoD conducts on the liquidation rates of foreign currency to determine the need for additional funding from the FCF. The lowest median indicates the more accurate method of forecasting as the forecast is relatively closer to the actual rate.

After calculating the APE for each currency by method, we conducted a bootstrap analysis on the median to examine whether the methods are statistically equivalent or different. The bootstrap method resamples each method's APEs with replacement to create a large number of sample statistics (Singh and Xie, 2008). In this case, the median is resampled 10,000 times to find a 95% percentile confidence interval around the median (using α=2.5% two-tailed interval). The bootstrap sample medians with confidence intervals are then compared to the other methods by overlapping confidence intervals. Should one method's confidence interval overlap another method, the two methods may be considered statistically equivalent. The entire APE distribution is utilized as the bootstrap sample for each iteration (i.e. an APE sample of n=752 means each bootstrap sample will also have 752 samples but with replacement for each sample taken from the original APE sample) (Ramsey, 2013). Fractional weighting was not used from the original sample APE's distribution for the bootstrap.

RESULTS

Table 2 provides the *mean* APE for each method by country from FY2006 to FY2014. The highlighted values illustrate which method produced the lowest *mean* APE for that currency. An average is taken of each country's APE by method at the bottom. Overall the private firm formulated the lowest mean APE for each forecasted exchange rate currency. The Random Walk had the lowest mean APE for three countries, while the status quo had the lowest mean APE for Iceland and Turkey. This was due to none of the other models having a forecast for those two countries. Removing those two countries from

TABLE 2
Mean APE from FY06 to FY14 by Country by Method

	Mean APE from FY06 to FY14					
Country	Status Quo	ARIMA	Random Walk	Forward Rates	Futures	Private Firm
Denmark	8.4%	12.3%	6.7%	7.1%		
EU	8.3%	16.7%	7.5%	6.3%	7.2%	6.0%
Iceland	19.7%					
Japan	13.6%	14.7%	13.5%	14.9%	12.2%	12.2%
Norway	8.5%	9.9%	8.3%	8.5%		
Singapore	10.1%	6.3%	5.6%			
South Korea	10.9%	11.9%	11.8%	10.5%		9.8%
Turkey	14.7%					
UK	8.76%	9.4%	8.4%	8.1%	7.0%	6.5%
Average	11.4%	11.6%	8.9%	9.2%	8.8%	8.6%

the analysis gives the status quo an overall average mean APE of 9.78%. Table 3 provides a more level comparison as only the countries that contain all methods are compared. The private firm maintains the lowest mean APE overall. From both tables, the use of futures prices was the second lowest average mean APE but did not have any one currency as the lowest APE. The use of forward rates in forecasting exchange rates was lower than the status quo. Selecting an ARIMA model as chosen by the lowest AIC among 27 possible models did not produce a lower mean APE than the status quo across either analysis.

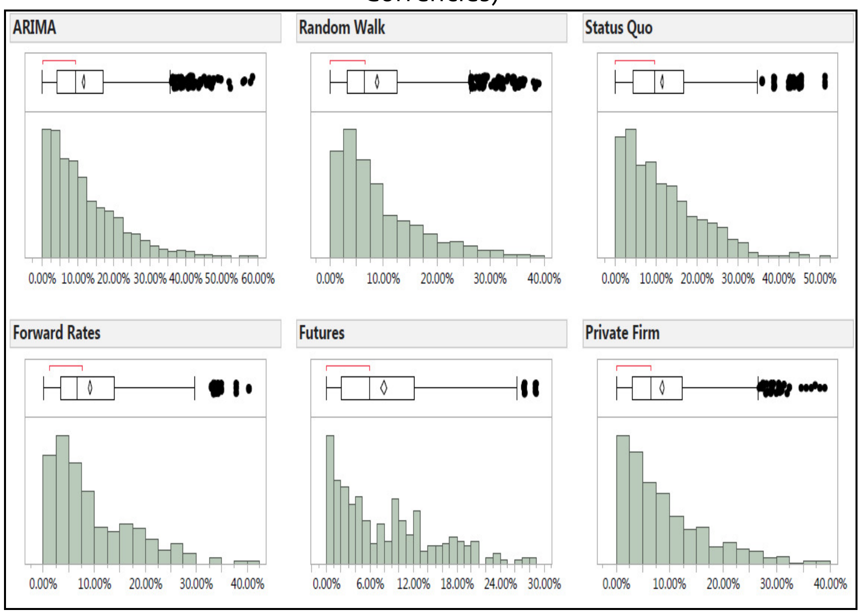
TABLE 3
Mean APE from FY06 to FY14 for the EU, Japan, and UK by Method

	Mean APE from FY06 to FY14					
Country	Status Quo	ARIMA	Random Walk	Forward Rates	Futures	Private Firm
EU	8.28%	16.70%	7.53%	6.33%	7.21%	6.03%
JAPAN	13.55%	14.71%	13.53%	14.89%	12.21%	12.16%
UK	8.76%	9.38%	8.39%	8.10%	6.95%	6.49%
Average	10.20%	13.60%	9.82%	9.77%	8.79%	8.23%

The distribution of each method's APEs, though, lends to comparing the results by median rather than mean. Graph 1 presents each method's APE for every currency the method forecasted an exchange rate. All of the distributions are skewed to the right with an abundance of outliers. Central tendency, then, is better represented by the *median* for a nonparametric analysis.

Table 4 is a reproduction of Table 2 with the median APE rather than the mean. The private firm forecasts are no longer clearly the lowest APE for every currency it forecasts. South Korea is the only country for which the private firm forecasts the lowest median APE while the Random Walk only maintains the lowest APE for Singapore. The status quo now has the lowest median APE for the Danish Kroner. The forward rates method has the lowest median for the EU and Norway. The futures method now forecasts the lowest median APE

GRAPH 1
Distribution of Each Method's Monthly APE from FY06 to FY14
(Bars Represent the APEs are for all Currencies)



overall and for Japan and Turkey. Table 5 compares the median APE only for the EU, Japan, and the UK. The method with the lowest APE is the futures method, as compared to the private firm forecasts in Table 3. ARIMA is consistent, whether in analyzing the APE by mean or median, in underperforming the status quo.

Looking beyond the simple statistics of mean or median, the research conducted a bootstrap to investigate whether the methods were statistically different. The bootstrap allowed for a 95%

TABLE 4
Median APE from FY06 to FY14 by Country by Method

Country	Median APE from FY06 to FY14

	Status Quo	ARIMA	Random Walk	Forward Rates	Futures	Private Firm
Denmark	4.67%	11.26%	5.56%	5.50%		

TABLE 4 **(Continued)**

	Median APE from FY06 to FY14					
Country	Status Quo	ARIMA	Random Walk	Forward Rates	Futures	Private Firm
EU	5.32%	13.26%	6.82%	4.56%	5.28%	4.90%
Iceland	16.50%					
Japan	15.42%	15.11%	12.04%	15.20%	10.80%	11.38%
Norway	6.91%	7.35%	6.59%	6.34%		
Singapore	10.12%	5.29%	4.79%			
South Korea	7.43%	8.76%	9.70%	8.08%		7.40%
Turkey	14.10%					
UK	8.97%	8.89%	6.34%	5.45%	3.93%	4.39%
Average	9.93%	10.34%	7.40%	9.23%	6.67%	7.02%

TABLE 5
Median APE from FY06 to FY14 for the EU, Japan, and UK by Method

	Median APE from FY06 to FY14					
Country	Status Quo	ARIMA	Random Walk	Forward Rates	Futures	Private Firm
EU	5.32%	13.26%	6.82%	4.56%	5.28%	4.90%
Japan	15.42%	15.11%	12.04%	15.20%	10.80%	11.38%
UK	8.97%	8.89%	6.34%	5.45%	3.93%	4.39%
Average	9.90%	10.34%	8.40%	9.23%	6.67%	6.89%

confidence interval around the median of each method. Any overlapping interval can be considered statistically equivalent. GRAPH 2 illustrates the median of each method along with the upper and lower bound of the confidence interval. Methods joined by a horizontal line are considered statistically the same. The forward rate, private firm, Random Walk, and futures methods have overlapping confidence intervals while the status quo and ARIMA share overlapping confidence intervals.

GRAPH 2
Bootstrap of the Median APE for each Method from FY 2006-2014

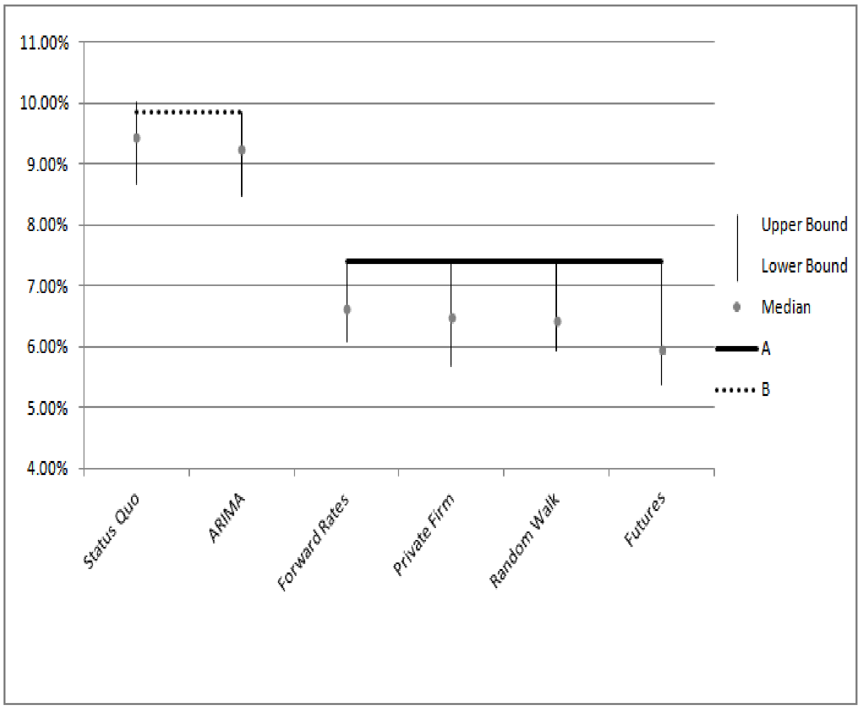


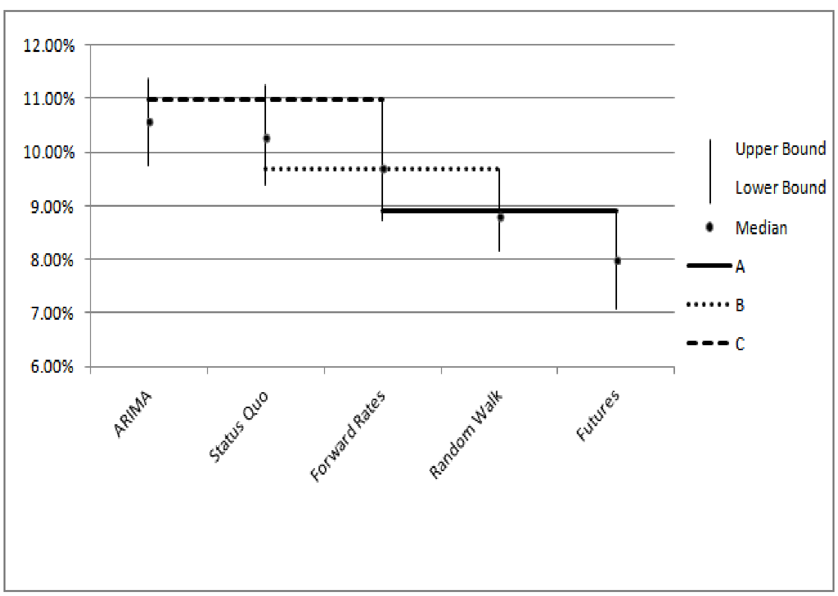
Table 6 is the comparison of median APEs for the longer time period (FY91 – FY12). The private firm forecasts were not available prior to FY06 and were not included for comparison. The distribution for this time period was similarly skewed to the right. The analysis, therefore, limited the use of the mean APE and focused only on the median. The futures method provides the lowest overall median APE and the lowest APE for Japan. The forward rate method is the lowest APE for the UK. ARIMA is the only method with a higher APE than the status quo across both countries.

TABLE 6
Median APE from FY91 to FY12 for Japan and the UK by Method

	FY91-FY12 Median APE for Countries and Average				
Country	Status Quo	ARIMA	Random Walk	Forward Rates	Futures
Japan	12.22%	13.01%	9.83%	13.63%	9.45%
UK	9.04%	9.06%	8.18%	6.07%	6.32%
Average	10.63%	11.04%	9.01%	9.85%	7.88%

GGRAPH 3 illustrates the bootstrapped confidence intervals for the FY1991 to FY2012 time period. Each method has an upper and lower bound for the confidence interval. Any methods with overlapping

GRAPH 3
Bootstrap of the Median APE for each Method from FY 1991-2012



interval may be considered statistically equivalent. Overlapping intervals are shown by a horizontal line. The futures, Random Walk, and forward rate method can be considered from a population statistically different from the status quo. The Random Walk and forward rate method, though, could also be from the same population as the status quo as shown by the dotted line "B" in the graph. Finally, as in GRAPH ARIMA and the status quo are statistically equivalent, but the forward rate method is now included in this grouping.

DISCUSSION

Can the government use the aggregated information of the markets to foster efficiency in its operations? The DoD's status quo of a center-weighted average failed to forecast better than four of the five methods over the short run. The forward rates, Random Walk, private firm and futures contracts each had lower errors than the status quo and are statistically different from the status quo. ARIMA was the only method to show statistical equivalence with the status quo. For the longer time frame, the forward rates, Random Walk, and futures contracts had lower errors, but only the futures contracts demonstrated strong statistical difference from the status quo. These findings conform to the literature. The Random Walk is still difficult to outperform while the use of forward rates in a DoD setting also showed strong performance more than a decade later. Auction theory supported the use of the price mechanism in future markets as an aggregator of pertinent information. The results of this study support the auction theory as the price of futures contracts held better forecasting power than other models, although it was not statistically different from every other model.

In practice, the theoretical difference in shifting from the status quo to futures contracts has real value for procurement officials. First, managers can reduce the holding accounts for risk mitigation against unfavorable currency swings and invest their capital more efficiently. Accurate forecasts, furthermore, give greater insight into contract negotiations (e.g. for multi-year construction projects). It allows setting a contract rate within reasonable standards and/or gives somewhat more accurate representations of costs associated with one contractor versus another (foreign versus domestic). Finally, these more accurate forecasts translate the economic benefits to the local community for new or in-place assets in foreign locations.

Judging methods by the median APE, the aggregation inherent in a market provides a better estimate than the status quo over the long term. Other methods with lower error than the status quo include the forward rate method and Random Walk model, which is expected from the literature review. This analysis, therefore, supports changing the method of forecasting foreign exchange rates for the annual DoD budget from the current status quo to the use of pricing available in the futures option market. Should the method fail to hold up to GAO standards, a private firm's forecasts, Random Walk model, or forward rate method could all outperform the status quo, although not as decisively as the futures market. Formulating a budget rate via this method provides a 3.23% reduction to the median APE (based on the short term period) and avoids $34 million in opportunity costs.

NOTES

1. The views expressed in this article are those of the author and do not necessarily reflect the views of the Department of Defense or any of its agencies.
2. The private company forecasting methodology contains proprietary information and is not subject to public distribution.

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